A CRITICAL ANALYSIS OF DIFFERENCES BETWEEN SHORT AND LONG TERM MEMORY

by

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I, the undersigned, declare that this dissertation has not already been accepted in substance for any degree and that it is not being concurrently submitted for candidature for any degree. This dissertation is the result of my independent investigation.

Michael M. Gruneberg.

TABLE OF CONTENTS

PUBLICATIONS

As a consequence of work undertaken in the preparation of this thesis a number of papers were accepted for publication.

Gruneberg, M.M. (1969)	Theoretical Note: Logical objections to a dichotomous theory of memory. Psychol. Rep. 24, 606.
Gruneberg, M.M. (1969)	The Limited Capacity Hypothesis and Short term memory. Acta Psychol. 31, 326 - 339.
Gruneberg, M.M. and Sykes, R.N. (1969)	Acoustic Confusion in long term memory. Acta. Psychol. 31, 293 - 296.
Gruneberg, M.M. and Sykes, R.N. (1969)	Semantic and Acoustic coding in short and long term memory. Psychol. Rep. 25, 849 - 850.
Gruneberg, M.M. (1970)	A dichotomous theory of memory - Unproved and Unprovable? Acta Psychol. In Press.
Gruneberg, M.M., Colwill, S.J. Winfrow, P. and Woods, R.W. (1970)	Acoustic confusion in long term memory - an extension of previous findings. Acta Psychol. In Press.

In addition a paper entitled "The limited capacity hypothesis and short term memory" was read to the Annual Conference of the British Psychological Society in Edinburgh, in April 1969.

SUMMARY

A CRITICAL ANALYSIS OF DIFFERENCES BETWEEN SHORT AND LONG TERM MEMORY

The thesis examines the empirical evidence claimed to support a distinction between short and long term memory. It also examines the logical status of such a dichotomous theory of memory. It is concluded that no evidence has yet been put forward which compels an interpretation of the data in terms of a dichotomous theory of memory. It is also considered that there are grave difficulties in ever establishing such a dichotomous theory on the basis of psychological evidence. If a dichotomous theory is, as the writer suggests, unproved, then the more parsimonious explanation of the data in terms of a single memory system, must be adopted.

The thesis commences with an examination of evidence claimed to support a dichotomous theory (ch.2) and considers the views of some writers who oppose a dichotomous theory interpretation (ch.3). The following chapter (ch.4) is concerned with the problem of establishing a dichotomous theory on the basis of the psychological evidence. It is noted that all the lines of evidence claimed to support a dichotomous theory depend on the assumption that rapid and less rapid forgetting have different underlying causes. Chapter 5 continues with an examination of theoretical problems, in particular the relationship between a recognition and recall. It is concluded that the empirical evidence does not require a dichotomy between recognition and recall in addition to a possible distinction between short and long term memory.

Chapter 6 is concerned with the nature of forgetting. It is concluded that no evidence unequivocally supports a trace decay or interference theory, or indeed any other theory of forgetting, over either the short or the long term. As long as this is the case it is concluded that a distinction between short and long term memory is unprovable.

The following chapters, 7, 8, 9, 10, and 11 deal with further empirical evidence claimed to support a dichotomy of memory systems. Chapters 7 and 8 deal with the limited capacity to retrieve newly presented material, and it is concluded that such evidence can be explained in single system terms. Chapter 9 deals with the claim that acoustic coding is confined to short term memory and semantic coding to long term memory. Empirical evidence is put forward to dispute this claim.

Chapter 10 deals with claims that the differential reactivity of the serial position curve to such variables as repetition, indicates a dichotomy of underlying memory systems. It is concluded that such claims cannot be substantiated in view of findings which show that conclusions based on serial position curve studies have no generality.

Chapter 11 considers the physiological evidence and questions its relevance to the controversy both on the grounds of the equivocal nature of the evidence and because it is not clear that physiological insult can inform normal memory functioning.

Chapter 12 reviews the positions outlined in chapter 2 in the light of considerations in the course of the thesis. No dichotomous theory appears adequate to handle the problems raised in the course of the thesis.

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ABBREVIATIONS USED IN THIS THESIS

VSTM	=	Very short term memory
STM	=	Short term memory
STS	=	Short term store
STMS	=	Short term memory store
LTM	=	Long term memory
LTS	=	Long term store
LTMS	=	Long term memory store
LCH	=	Limited capacity hypothesis
ECS	=	Electric convulsive shock

CHAPTER 1

INTRODUCTION

This thesis is basically concerned with an analysis of differences between memory over the short and the long term. It is hoped that such an analysis will reveal that current accounts of the nature of memory, in terms of two dichotomous systems, one of short duration and labile nature, the other of long duration and stable nature, are not only unproved, but also probably unprovable. This being the case parsimony demands that the most economical explanation of the phenomena under examination - a single system theory explanation, be adopted. In other words, the thesis aims at showing that no evidence has yet been produced which establishes a dichotomous theory of memory, in which information enters a short term memory system prior to transfer to long term memory or to forgetting. Furthermore the aim is to show that it is unlikely that evidence can be produced which will establish such a theory.

Almost the first impression gained by someone entering the field of memory is the extent to which disagreement reigns on the most fundamental of issues. The domain of short term memory itself varies as each item of experimental evidence in support of a dichotomy arises, and estimates of its duration of 1 - 10 seconds, (Wickelgren 1969a), 15 - 30 seconds, (Atkinson and Shiffrin 1968), of one or two minutes to one hour (Broadbent 1967), or even as defying analysis in terms of time (McGaugh, 1967) have been made. Even one of the major opponents of a dichotomous theory, Melton 1967 a) is unsure whether the term "short term memory" can be applied to the first 15 seconds after information has been taken in, and reserves the term "short term memory" to phenomena occurring after this period of time. Earlier phenomena are claimed to occur in "very short term memory" (VSTM). Elsewhere Melton (1963) distinguishes between pre- and post- categorisation forgetting. The present writer takes a considerably more radical view than Melton in claiming to show that information <u>once categorised</u> cannot be shown to be entered into a short term memory system before transfer to long term memory. This categorisation is almost instantaneous and almost certainly occurs within a second of presentation of any information, not the 15 seconds that Melton is willing to allow. This claim is made on the basis of information being classifiable as meaningful within such short time intervals (e.g. the understanding of words that are read) and thus post-categorised.

The present thesis is, as far as the writer is aware, only the third major attempt to analyse critically a dichotomous theory of memory. This is not, of course, to claim that only Melton (1963) and Postman (1964) and the present author have questioned the theory. Brown (1958), Keppel and Underwood (1962), and many others have opposed a dichotomous theory and many more have expressed doubts. Nevertheless, Melton's paper (1963) and that of Postman (1964) are the only major papers systematically attacking a dichotomous theory and the present thesis is, as far as the writer is aware, the ohly systematic attempt to attack the theory taking developments since 1964 into account.

The plan of the thesis is as follows. The next chapter will outline briefly the theoretical positions of the main workers in this field, tracing the development of a dichotomous theory from Hebb (1949) through to contemporary workers such as Atkinson and Shiffrin (1968), Waugh and Norman (1965) and Glanzer et al (1969). Chapter 3 considers papers critical of dichotomous theories e.g. Melton (1963) Postman (1964) and others. Chapter 4 will concern itself with some of the critical theoretical issues which must be considered before understanding of the problem can take place. In particular a consideration of the criterion by which it is decided that material is in one system rather than another is analysed, as is a consideration of the evidence which would be necessary to establish a dichotomous theory. Chapter 5 also concerns itself with another important theoretical issue, the relationship of recognition to recall. Chapters 4, 6, to 12 are concerned with the empirical evidence for a dichotomous theory of memory. Chapter 6 will analyse the evidence for a dichotomy on the basis of different causes of forgetting as between STM and LTM. Chapter 7 will show that a dichotomous theory cannot be established on the basis of the limited capacity to recall recently presented information; Chapter 8 will show that the experimental evidence produced by the writer is not easily accounted for in terms of the limited storage capacity hypothesis. Chapter 9 concerns itself with the evidence for different interference effects in the two purported systems. Chapter 10 looks at the evidence for a dichotomy between STM and LTM on the basis of variations in the serial position curve as a result of experimental manipulation. Chapter 11 reviews the literature on amnesia relevant to the present controversy. Chapter 12 re-examines the theoretical positions outlined in Chapter 2 in the light of the empirical and logical considerations presented subsequently. Finally chapter 13 summarises briefly the main points which have arisen in the course of the thesis.

CHAPTER 2

THEORETICAL FORMULATIONS OF A DICHOTOMOUS ~~THEORY OF MEMORY;~~

AND THE SUPPORTING EVIDENCE.

This chapter will look at the main theoretical formulations of a dichotomous theory of memory, and at the evidence which is used to support such theoretical frameworks. Dichotomous theories will be taken to be those theories which postulate two or more temporally separate memory systems, a short term memory system, lasting at most two to three minutes, and a long term memory, lasting from two to three seconds to years.[ø] As Melton (1963) however, pointed out, up till 1963 no publication had systematically considered the contrasting characteristics of STM and LTM, and perhaps only the paper of Murdock (1967), and to a lesser extent the book on "Human Memory" by Adams (1967) can be said to have rectified the position. Perhaps the failure to consider a dichotomous position systematically up till the time of Melton's writing, is related to the relative lack of interest until recently, in this particular aspect of memory.

Thus whilst the postulation of at least two separate memory systems is not new in the history of psychology, James having suggested this as long ago as 1890, little real interest was taken in the problem until fairly recently. Perhaps a re-awakening of interest in the problem can be attributed to Hebb (1949). In his now classic book

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Footnote. The time overlap takes account of theories which postulate the simultaneous existence of short and long term memory.

"The" Organisation of Behaviour", Hebb suggested that the rapid decay of items from immediate memory is due to their physiological representation being in the form of an activity trace, with a rapid trace decay rate, rather than in the form of any structural change in the physiology of the brain, which is presumed to underly the storage of material which has not been forgotten over longer periods.

Hebb in fact, does not appear to have much to say about the psychological evidence which would lead one to seek neurophysiological explanations of memory in terms of two memory systems. He does, however, point to transient memories and at the same time points to the need for long term structural memory. Hebb's main emphasis, however, was on the physiological possibilities of a dual trace system. In addition to Hebb, therefore, the theoretical positions of the following writers will be considered briefly in turn: Broadbent, Bower, Peterson, Glanzer, Waugh and Norman, Norman, Wickelgren, Weiskrantz, Adams, Atkinson and Shiffrin, and Tulving.

Broadbent's theory

With Broadbent (1958, (1963), a dichotomous theory is somewhat more explicitly stated in psychological terms. Broadbent (1963) makes a clear differentiation between pre- and post-categorisation memory (the former being more commonly referred to now as very short term memory (e.g. Wickelgren 1969a). It is this post-categorisation short term memory which Broadbent also regards as being subject to autonomous trace decay which clearly marks him as a dichotomous theorist, and indeed he regards the function of the paper as, in part, summarising the evidence for a dichotomous theory, i.e. evidence which distinguishes short from long term memory. Whilst the evidence which Broadbent uses will be outlined presently, it is important to establish at once the relationship between the P and S systems previously outlined by Broadbent (1958) and short term post-categorisation memory. Broadbent (1963) regards information as entering the nervous system through a limited capacity channel. Once through this channel, items can be held in a short term store, but only as long asthey can pass through the same limited channel capacity as that by which they arrived.* Broadbent (quotes the example of a telephone number which is not forgotten provided new information does not arrive. It seems reasonably clear that Broadbent is talking of the P system when talking of the limited capacity channel, and of the S system when talking of <u>short term memory store</u>. This is important because the S system must not be confused, as it might easily be, with long term memory. The distinction which Broadbent makes between two kinds of short term memory cannot be overemphasised.

The evidence which Broadbent puts forward in support of the view that post-categorisation short term memory can be distinguished from long term memory, rests basically on the assumption that rapid forgetting is time dependent whereas forgetting over longer periods is material dependent. In other words, Broadbent is arguing for the classical distinction between STM and LTM, that STM forgetting is due to trace decay, LTM forgetting to interference. The actual evidence quoted is that of Conrad (1960) and Conrad and Hille (1958), in which time, rather than the amount of interfering material seems to affect forgetting over the short term. Broadbent also uses evidence of the different effects of overt and covert rehearsal, the former being hypothesised to be slower and therefore showing the greater effects of time along on forgetting.

* However it should be noted that Broadbent put the S system before the P system in 1958.

Broadbent does admit that the evidence that short term forgetting is purely time dependent is not too convincing, but points out that there is not very much evidence that similarity factors result in forgetting, whilst such evidence is plentiful for longer term forgetting.

Broadbent then, restates the position of Hebb, pointing to psychological evidence. As Neisser (1967), however points out, he is not at all explicit as to the theoretical relationship between STM and LTM. His theoretical work up to 1963 can best be seen in terms of describing a model for VSTM and STM, rather than STM and LTM.

Finally Broadbent (1967) makes two points which are of importance. On P. 40 he admits that the memory span evidence for limited capacity contains a long term element, and admission which distinguishes him from other dichotomous theorists, such as Adams. Secondly on P 94, he admits that differences between STM and LTM may be differences in degree, but the degree is so drastic that one should distinguish them. To take this position is clearly inconsistent with what he has previously claimed, in that trace decay and interference are different in kind, not degree.

Bower's theoretical position

Bower (1967) is somewhat more explicit than Broadbent on the nature of the relationship between STM and LTM and quite explicit as to at least one criterion for distinguishing material in the two systems. On P 134, in an exchange with Melton on how to tell whether an item was in STM or LTM, Bower states explicitly that it was in STM "Because they can forget it." (One feels that Melton ought to have known better). Elsewhere (1964) he uses the example of rapid forgetting following shock to indicate a separate STM and again in 1967 on P 122 he notes that ECS or shock results in loss of material in STM but not LTM. It is somewhat sad therefore that Bower allows that the effect of drugs might be to cause forgetting of items recently placed in LTM, as it marks a clouding of an otherwise clear statement as to the criteria by which material claimed to be in STM and LTM are to be distinguished.

As to the relationship between short and long term memory, Bower regards an item as residing in STM at risk of being lost in an all or nothing manner, unless rehearsal results in it being copied into long term memory. As with other theoretical formulations, such as Waugh and Norman's (1965) an item can be resident in STM, LTM or both. Clearly, however, Bower regards LTM as a stable memory system not usually subject to forgetting of a rapid nature.

Finally, his views on recognition within a short term, long term memory context are clearly at variance with those of some other dichotomist theorists, notably Adams (1967), in that Bower claims, P 168, the long-short model has no natural way to accommodate within its conceptual framework any distinction between recognition and recall.

Peterson's Theory

Another theorist whose contribution to the study of memory has been of the greatest stimulus and benefit is Peterson. Peterson and Peterson (1959) discovered that even very short sequences (3 letter trigrams) could be rapidly forgotten after a single exposure, thereby holding up for experimental investigation a vast number of variables under conditions of interest both to the experimenter and to the subject. The full significance of Peterson and Peterson's (1959) experiment was not appreciated even by Peterson for a little time. They conceptualised a brief presentation of trigrams as a learning trial; latencies resembled that of recall in a learning experiment and repetition improved recall in an orderly fashion. However, it soon became apparent that rapid forgetting in the absence of rehearsal for a three letter trigram could be used by trace decay theorists to support a trace decay theory of short term forgetting, and hence a dichotomy between short and long term memory - long term forgetting being generally accepted as resulting from interference.

Since then Peterson has advocated a dichotomous theory of memory on a number of occasions (e.g. 1963, 1966a, 1966b) and his theoretical position is now considered.

Peterson (1966b) does consider that evidence on trigram forgetting supports a trace decay theory of forgetting for memory over the short term. Along with other lines of evidence, he interprets evidence of differences in retention probabilities for the first trigram of a sequence as a function of mode of presentation, as favouring an autonomous trace decay theory. Keppel and Underwood (1962) showed that under conditions of visual presentation there was no forgetting of the first trigram of a sequence. When however the presentation was auditory a certain amount of forgetting was observed. As Peterson points out it is difficult to attribute such forgetting to Proactive interference, so that it is not unreasonable to suppose that autonomous trace decay does sometimes occur, but is not always measurable. It must be stressed that Peterson like Brown (1964) does not deny the role of other possible mechanisms of forgetting in the short term. Yet he clearly considers that the presence of a decay factor is considered to be one type of evidence for the existence of a short term store.

Peterson considers that there are learning mechanisms in short as well as long term memory, but suggests that there is also a recency mechanism which masks the operation of learning which is initiated immediately. Memory for recent events is largely affected by this short term mechanism and memory drops off rapidly when events of the same class follow each other. On the other hand memory for events in the more distant past is made possible by learning mechanisms and it need not decrease over the course of short intervals, but may increase. Peterson also conceives of the long term store being of such a nature that items in it are, for a time, more available than newly presented items in the short term memory. Peterson's evidence for a recency mechanism rests on the evidence that the rapidly declining part of the forgetting curve is differently affected by certain variables, as compared to the asymptote. Thus for example, the number of presentations, their duration, and their spacing differentially affect the rapidly falling part of the forgetting curve and the asymptote. Whilst Peterson bases these conclusions on evidence from paired associate studies, it is clear that this kind of evidence is related to the evidence provided by Glanzer and Cunitz (1966) and later workers using the serial position effect for free recall as evidence of a dichotomous theory.

Peterson (1966c) like Tulving (1968) makes use of the reminiscence effect to support a dichotomous theory. He also uses (1966a) the evidence of Peterson et al (1963) who showed avoidance of responses recently given in an anticipation task, presumably because the subjects know it must be wrong because of its recent presentation. This recency mechanism which enables this to be done is considered akin to a running memory span. It is perhaps noteworthy that evidence for reminiscence of recently presented items after a period of less than 30 secs., which is used by Peterson as evidence for a dichotomy - switching to a more efficient secondary system, contrasts with evidence of a dichotomy produced by Glanzer and Cunitz showing degradation of the most recently presented items over a period of 30 seconds. In other words both the better and worse performance on the most recently presented items after short periods of interpolated activity are used as evidence of a dichotomous theory of memory by different dichotomous theorists.

Glanzer's theory

The theoretical position of Glanzer is enigmatic in various ways. In his first major theoretical paper on a dichotomous theory he proposed that STM was unlimited with respect to capacity, whereas LTM was limited, and that this was true by definition (Glanzer and Cunitz, (1966)). This is at variance however with almost all other formulations of a dichotomous theory, and Glanzer (Glanzer et al 1969) has now come back into line, regarding STS (Short Term Store) as limited to some 3 - 6 items.

Glanzer's main position outlined in a number of papers - Glanzer and Cunitz (1966) Glanzer and Meinzer (1967) Glanzer (1969) and Glanzer et al (1969) is that the serial position curve produced from a free recall task, indicates output from two memory stores. The early and middle part of the serial position curve indicate output predominantly from LTM, whereas the recency part of the curve indicates output from STM (Glanzer and Cunitz 1966). Glanzer and Cunitz base this conclusion on the differential effect of variables on the early and later parts of the serial position curve. Thus, for example, interpolation of activity between presentation and recall affects the most recently presented items only, causing a degradation in performance, whilst rate of presentation affects the earlier part of the serial position curve only. Glanzer and Meinzer (1967) produce evidence that repetition decrements all but the last few positions.

Glanzer (1968) produces evidence which closely resembles Peterson's recency mechanism evidence when he demonstrates that the greater the distance between associated words, the less is there an effect on recall. In his most recent paper Glanzer (Glanzer et al 1969) claims that it is the number of items following presentation, not the time interval, which has an effect on the most recently presented part of the serial position curve.

At the present time, then, Glanzer believes STS (Short Term Store) to be a limited capacity buffer store, capable of holding some 3 to 6 items. Incoming items result in some items being either transferred to LTS (Long Term Store) or lost, and displacement is regarded as the cause of forgetting in STM.

Waugh and Norman's Theory

Waugh and Norman make James' (1890) distinction between Primary and Secondary Memory (PM and SM denoting the two stores). Unlike James, however, they regard PM as encompassing a certain number of events, rather than time, a displacement theory of short term forgetting, rather than autonomous trace decay. "Every verbal item that is attended to enters PM. As we have seen, the capacity of this system is sharply limited. New items displace old ones; displaced items are permanently lost. When an item is rehearsed, however, it remains in PM and it may enter into SM." An experiment reported in the course of their paper, which showed forgetting to be dependent on the number of interpolated items rather than time, was the evidence which led them to conclude that forgetting in PM is due to displacement, which they regard as encompassed by an interference theory of forgetting. They do not consider the cause of forgetting in long term - secondary memory, but there is no evidence to suggest that they do not regard it also as being caused by interference.

An important aspect of their theory is that PM and SM can to some extent overlap, and they consider that many experiments on short term memory are really measuring a composite of output from two storage systems (a view also shared by Glanzer et al (1969)).

The evidence that Waugh and Norman put forward for supposing that the serial position curve represents output from two storage systems is also similar in kind to that of Glanzer, the differential effects of variables, for instance on what is basically the middle and end of the serial position curve and the claim that the probability of recall of an item from PM depends on the number of interpolated items between presentation and recall, unlike SM.

Waugh and Norman also appeal to introspection, and point to the "echo box" phenomenon, in which the most recently presented items can be effortlessly "Parrotted" back. Clearly this has much in common with Peterson's recency mechanism.

Norman's Theory

Norman (1968, 1969) has restated some of the ideas presented in the Waugh and Norman paper, together with some additional material. Like Broadbent and Peterson, Norman (1969) distinguishes between a visual information storage (VSTM) and immediate memory. On P 81 he states "In the models of Chapter 4, the output of visual short term memory entered an auditory information storage. That auditory storage is the immediate memory of this chapter". Apart from making the distinction between the type of very short term memory that is the subject of Sperling's (1960) work for instance, Norman is clearly stating the position that auditory coding is a characteristic of STM, a position that he restates on P 127-128 when using evidence from Baddeley (1966a,b) to draw a distinction between STM and LTM.

Norman does differ from other dichotomists in taking the view that the limit in immediate memory capacity might be in terms of the limit of rehearsal capacity, rather than mere storage capacity.

Norman's Psychological Review paper (1968) makes many of the points made elsewhere. For instance a dichotomy between STM and LTM is maintained because retention of material in "primary storage is affected by acoustical similarity among the items which are to be retained, whereas in secondary memory, semantic similarity has the same effect." Yet Norman is clearly unhappy about a dichotomous theory of memory. He points out that for a transformation from visual to acoustic coding to take place material in secondary memory must be utilised. Again he attacks a box dichotomous theory which implies that material is stored in one box (Primary storage) before it can be transferred to another. "The trouble with such a theory lies in the assumed separation between the two systems. Perceptual recognition of words and of familiar sensory input requires, at the least, that we be able to find some representation of the inputs in secondary storage. If the box theory is held, there must be sufficient interconnections between the storages to allow a comparison of just-perceived sensory events with the collection of previously experienced perceptions. This intercommunication must be so direct and complete that a formal distinction between the two storage systems becomes difficult to make. In fact with sufficiently complex interactions the two systems become equivalent to one." It seems reasonable to suppose that Norman is at this point more or less abdicating a dichotomy.

In fact this is not the case. Norman regards PM and SM as different properties of the same physical device. He goes on to describe a model similar to Hebbs', in which temporary traces appear as a result of initial activation, which dissipate unless some action is taken to maintain them. Permanent changes in storage occur when there has been reactivation of temporary traces. However, because Primary traces are continually changing, whereas secondary traces are passive and permanent the two storage modes have different retrieval p properties.

Again the distinction between visual storage and short term memory is stressed, Sperling's (1967) visual information and Neisser's (1967) echoic and iconic storages being within the compass of such a sensory storage, whereas Sperling's auditory information storage and Neisser's active verbal memory are the same as primary storage.

Wickelgren's Theory

Like Norman, Wickelgren (1969a) has his reservations about certain claims made by other dichotomous theorists, but nevertheless holds a dichotomous theory. Wickelgren, in fact proposes a trichotomy between STM, Intermediate Term Memory (ITM), and LTM, and regards the time interval of STM as about 10 seconds, of ITM from 2 minutes to several hours, and LTM from several hours to days and years. Clearly much of the experimental work in memory on the differences between STM and LTM would be regarded by Wickelgren as representing differences between STM and ITM. (He also distinguishes a fourth category in fact, very short term memory - "visual" - a precategorisation store.

Wickelgren (1969a) does not use differences in coding over time as evidence for a dichotomous theory of memory, indeed he points to evidence of conceptual coding after about 1 sec., and predicts acoustic coding in LTM. (In another paper however, (1969b), he does appear to be suggesting a distinction in terms of coding.)

Wickelgren regards the question of whether trace decay curves indicate a decrease in the rate of decay with age, or whether they are the sum of several exponentially decaying ones as critical.

Whilst Wickelgren would appear to subscribe to the view that STM has limited capacity, much of this work has aimed at showing that it is not of a non-associative (buffer storage) type and he has demonstrated the effects of acoustic similarity on STM (1956a).

Elsewhere (1968) Wickelgren believes that evidence of a clinical nature clearly indicates a distinction between short and long term memory.

Weiskrantz's Theory

The dichotomous theory proposed by Weizkrantz (1966, 1967) also relies heavily on "Physiological" data, specifically on the effects of electro-convulsive shock on memory. Weiskrantz notes that amnesic effects of ECS might extend to material in the memory system for several weeks, and therefore beyond any possible short term, dynamic trace. Part of the effect of ECS therefore is to produce interference phenomena in LTM, which results in material being forgotten in LTM. As the interference subsides, so recovery of LTM is to be expected, and indeed this is in line with clinical findings. Weiskrantz still maintains however, that there is evidence of a separate, dynamic short term memory system, on the basis of evidence from ECS, because amnesia following ECS never seems to recover fully, and this appears particularly true of material taken in up to 5 seconds before shock.

For Weiskrantz then, the relationship between STM and LTM is conceived to be similar to that envisaged by Hebb, with a dynamic, short-lived memory, subject to rapid decay, and a stable, long term memory, subject to interference effects.

Adams' Theory

Physiological evidence is also one of the three lines of evidence which Adams (1967) proposes as supporting a dichotomous theory of memory, the other two being the limited capacity of short term memory to store items for recall and the differing interference and coding systems in short and long term memory. Specifically he claims that STM is an acoustic coding system, whereas LTM employs semantic coding, and bases this conclusion on the work of Conrad (1964) Baddeley (1966b) and Wickelgren (1965a), (1966).

The physiological evidence upon which Adams bases his theory is that produced by Milner e.g. (1959), which indicates rapid memory loss following certain types of brain lesion, whilst at the same time older memories are spared.

Adams' theoretical position is in many respects different from many other dichotomous theorists, particularly his views on rapid forgetting and the nature of the difference between recognition and recall. To Adams the problem of trace decay or interference as the cause of rapid forgetting has been resolved in favour of the latter, on the basis, basically, of the experiments of Keppel and Underwood (1962) and Waugh and Norman (1965). What Adams means by Interference however, and what many other writers mean e.g. Melton (1967a) Hilgard and Bower (1966) are somewhat different. For Melton and Hilgard and Bower, interference as a theory of forgetting means more than that the effects of previous experience and similarity factors are operationally measurable on a memory task; it means specifically that the cause of forgetting is due to factors other than loss of stored material. It must be admitted that Adams is not alone in using interference as a purely operational term; Wickelgren (1969b) does not appear to be using the term in its classical and usual sense.

In regarding forgetting in short term memory as being due to interference rather than trace decay, Adams is clearly stating a position which differs radically from Hebb and Broadbent, for instance, although it is perhaps not far removed from the position of Waugh and Norman (1965) who also regard interference theory in a somewhat different light from others.

The most important difference between Adams, and all other dichotomous theorists, with the exception of Atkinson and Shiffrin (1968) is , as far as the writer is aware, the denial by Adams that rapid forgetting per se is a characteristic of short term memory. (P 136). In this writer's view this statement shows a complete misunderstanding on the part of Adams, of the nature of the problem, and indeed Hilgard and Bower put the central problem (P 506) as "How best to explain the decrements in short term recall" i.e. rapid forgetting.

The other relevant point of difference between Adams and most other psychologists concerns the relationship between recognition and recall. Adams regards recognition and recall as indicating two dichotomous underlying memory states, rather than the almost universal assumption that the difference lies in the nature of the retrieval mechanism (e.g. Norman and Wickelgren 1969). Adams regards recognition as some form of S Perceptual trace, somewhat akin to an image. It is ".....a stimulus attribute whose strength was defined by frequency of stimulus occurrences and independent of responses learned to the stimulus." "As far as memory is concerned, the S Perceptual trace is reactivated by the original stimulus at the recognition test and causes the subject to identify it as old". P 265.

Apart from having implications for an experimental resolution of any problem in the field of memory, Adams' position has implications for a formulation of a dichotomous theory of memory. As presented there are clearly 4 possible memory systems, rather than two, a short and long term memory system both for recognition and recall. Adams' dichotomy for the most part would appear to be of recall mechanism, although he is not averse to using recognition experiments to dispose of problem theories of a more general nature (e.g. Hebb and Foord's study

(1945) is used to dispose of autonomous trace transformation theory).

For Adams, then, STM can be regarded as a separate compartment from long term memory, on the evidence that different principles would appear to apply over the short and the long term. There may be intercommunication between STM and LTM although this is taken to depend on the nature of material.

Atkinson and Shiffrin's Theory.

Perhaps the most explicit statement of a dichotomous theory is by Atkinson and Shiffrin (1968). Like Broadbent, Wickelgren and Norman, they too distinguish between a short term sensory store and short term memory, but make no distinction between intermediate and long term memory. In addition Atkinson and Shiffrin distinguish between central processes, such as rehearsal, which are under the control of the individual, and structural aspects of memory, such as the nature of storage systems.

Atkinson and Shiffrin view information, upon being taken in, as residing in a short term sensory store, the store which decays in a matter of milliseconds according to the evidence of, for instance, Sperling. Information then enters a short term store, in which information is assumed to decay and disappear completely, but the time required for the information loss is considerably longer than for the sensory register. The character of information in the short term store does not depend necessarily on the form of sensory input, but visual input may be held in an auditory short term store. Atkinson and Shiffrin do, however, stress that it is difficult to separate auditory, verbal and linguistic aspects of short term memory and use the abbreviation a.v.l. to indicate the nature of STM store. Again on P 93, they note that most experiments in the literature dealing with long term store, have been concerned with storage in the a.v.l. mode, but "it is clear that there is long term memory in each of the other sensory modalities, as demonstrated by an ability to recognise stimuli presented in these senses." Thus they clearly do not distinguish STM from LTM on the basis of different coding systems being employed by the two memory stores, as others, e.g. Adams, have done.

The rate of decay of STM is claimed to be difficult to estimate because of the influence of central processes such as rehearsal; however they claim that the evidence suggests a decay rate of between 15-30 seconds.

The long term store differs from the others in that information which enters this system is not lost and does not decay in the same manner. Indeed in another paper (1969) they claim that in LTM information is never lost from store. Whilst all information is eventually lost from the sensory register and STM, information in LTM is relatively permanent although it may be modified or rendered temporarily irretrievable as a result of other incoming information. (P 93). On P 127, however, they do admit that rapid forgetting is possible, of material entering long term memory.

The basic evidence upon which Atkinson and Shiffrin base a dichotomy between short and long term memory is the work of Milner (1959, 1966, 1968), on the effect of hippocampal lesions upon memory, in which newly acquired information is lost in a period of about 30 seconds, whilst old material is retained.

Atkinson and Shiffrin are somewhat equivocal about the nature of transfer of material between the sensory store, the short term store and the long term store. Whilst they regard transfer from

STS to LTS as primarily a function of central processes, it is also an unvarying feature of the system, so that whilst information is residing in STS, transfer is taking place to LTS. They suggest that evidence from incidental learning supports this view, as well as evidence from Hebb (1961) who provided evidence of permanent storage even though subjects were not trying to store material in LTS. It might therefore be reasonable to interpret rehearsal as having the function of maintaining material in STS so that transfer can take place (P111). Indeed on P 111 they state "In terms of STS structure, we can imagine that each rehearsal regenerates the STS trade and thereby prolongs decay". and on P 128 "We assume here that LTS increases linearly with the time an item resides in the buffer."

Again when dealing with transfer from sensory register to STS and LTS Atkinson and Shiffrin are equivocal. On p 115 they note "In general, information entering STS comes directly from LTS and only indirectly from the sensory register." They use the example of a word, where verbal representation is sought in LTM for entry into STM. The sensory aspects of a word are matched in LTM until a verbal representation is found. To this writer it appears that this entails information from STS entering LTS direct. Yet the following passage on P 96 is worth quoting:

"In the case of transfer from the visual image to the a.v.l. store it seems likely that a selective screen is made at the discretion of the subject. As each element in the register is screened a matching programme of some sort is carried out against information in long term store, and the verbal "name" of the element is recovered from long term memory and fed into the short-term store.

.........Its communication between the sensory register and long term store does not, however, permit us to infer that information is transferred directly to long term store from the register".

A further point made by Atkinson and Shiffrin, with which the writer wishes to take issue at this point, concerns the notation used by these authors. They claim it is important not to confuse the terms STS and LTS with the terms LTM and STM, a position which is of course unexceptionable. STM refers to memory examined in experiments of short duration. However, in claiming that STM may contain both STS and LTS and hence not be amenable to a dichotomous or single system interpretation, they fail to appreciate that attempts have been made to dichotomise STM and LTM on grounds other than storage. Such a distinction has been made by Tulving (1968) on the basis of differing retrieval effects. In other words, it is reasonable to make the distinction between STS and STM, but this cannot be taken to mean that it is illegitimate to dichotomise between STM and LTM rather than STS and LTS.

Tulving's Theory

Tulving's (1968) theory is in fact completely different from any other, in that he claims the dichotomy between short and long term memory should be on the basis of dichotomous retrieval systems, whereas other theorists have assumed the difference to lie in storage mechanisms. He also differs from most theorists, apart from Adams, perhaps, on his views of the relationship between recognition and recall. On P 27 he bluntly states, without recourse to empirical evidence "Scores on a recognition test are determined by different retained information from that measured by recall tests."

The distinction between retrieval and storage which Tulving makes is in terms of the potential availability of information in the storage, and the accessibility of this information. This difference is indicated by experimental data which indicates that a subject can recall more items at a later time than at an earlier time, without the necessity of interpolated presentations. Clearly this indicates that the retrieval "Mechanism" does not have access to all the available information in store.

It does not, of course, show that there is any need to hold a dichotomy between short and long term memory, based on retrieval systems; although Tulving uses evidence of differential effects of variables on the shape of the serial position curve to draw this conclusion. Thus, he quotes evidence from Murdock (1962) Postman and Phillip (1965) Glanzer and Cunitz (1966) and Glanzer and Meinzer (1967) who have shown the recency effect, unlike earlier portions of the curve, was independent of rate of presentation, of test length and of repetition. On the other hand, the recency effect disappeared with an interpolated activity lasting 30 seconds.

On P 12 Tulving states "All these findings, in showing that certain experimental variables affect one part of the serial position curve whilst leaving another invariant, strongly suggest that the curve reflects the operation of two types of recall mechanism". It is perhaps surprising that as Peterson (1966 c) too has suggested, a dichotomy on the basis of retrieval recovery over time, Tulving should not consider Peterson's simple explanation of Glanzer and Cunitz's findings on the effects of interpolation of activity on the shape of the serial position curve.

Tulving goes on to consider the interpretation of the serial position curve given by Waugh and Norman (1965) in so far as it is relevant to a dichotomous theory of memory, and points out that they equate retention with recall, which is, as has been pointed out above, not satisfactory. Tulving therefore prefers the view that all information is stored in the same unitary storage system, and that differences in recall of early, late and middle items reflect primarily differences in the accessibility of these items. P.13 "Late input items may be retrieved more easily because of certain kinds of additional auxiliary information, stored with each item at the time of presentation, and not available for items perceived earlier. The acoustic trace of an item the subject hears.......may be one kind of such auxiliary information that might serve as a retrieval cue for the item. Such an acoustic trace may rapidly decay..... even if its loss does not affect the rest of the information stored in input. The item for which the acoustic trace is lost may still be potentially retrievable through other, <u>less powerful but more permanent retrieval cues</u>."

It is not entirely clear, from this passage, what Tulving means by separate retrieval mechanisms. It seems that he is advocating changes in storage affecting the possibilities of retrieving an item. After all, the acoustic trace is part of the stored material, even if it did not initially "belong" to the original item. More difficult is the interpretation of Tulving's theory in terms of a dichotomy. The evidence produced to support a dichotomy, variations in the serial position curve as a result of experimental manipulation, say nothing about acoustic or any other added traces which decay rapidly, and this is the evidence needed for a dichotomy based on the grounds Tulving claims. After all it is not inconsistent with a dichotomous position to say it is the actual item which is decaying rapidly - indicating storage. Perhaps the use of different cues enables previously inaccessible material to be recalled. This analysis of Tulving's position at this juncture is intended to indicate that Tulving in fact presents no evidence to justify his position on a dichotomy, i.e. that there are dichotomous retrieval as opposed to storage systems.

A modal model for a dichotomous theory

Murdock (1967) in what is probably the most systematic review of dichotomous theories of memories, has suggested as a result of such a review, a "modal model" - a synthesis of the various views put forward. The model is as follows:

Items enter a sensory store, and if attended to, and processing demands are not too great, pass into Primary memory, which is a system of limited storage capacity. Whilst in Primary memory, items can be copied or transferred into Secondary memory, and rehearsal is a critical variable.

Three forgetting mechnisms are suggested: decay from the sensory store; displacement from Primary memory; and interference from Secondary memory. Finally it is noted that items can reside in PM or SM or both; the two storage systems are not mutually exclusive.

Murdock makes no claim that his model is the true dichotomous model (clearly it is not) and whilst it is useful to have Murdock's synthesis, it is also useful to see at what points dichotomist theorists themselves differ.

Some disagreements

Whilst most theorists agree that items enter STM from a sensory register, this is not true of Atkinson and Shiffrin, who regard items as entering STM from LTM. The nature of STM is disputed by Tulving, who regards it as part of the same storage system as LTM and presumably therefore not limited in storage capacity. Rehearsal is regarded as critical by some dichotomist theorists in transferring from STM to LTM (e.g. Waugh and Norman) but only as important by others e.g. Atkinson and Shiffrin, who regard transfer as automatic if material resides in STS.

The cause of forgetting in STM is considered to be autonomous trace decay by Broadbent (1963), displacement by Atkinson and Shiffrin (1965), interference by Wickelgren (1965), and Adams (1967), and when one considers that the whole question of a dichotomy of memory systems resolves itself around the cause of forgetting in the short term (Hilgard and Bower 1966) this must be regarded as a most serious state of affairs for a dichotomous theory.

Summary of Evidence

The evidence for a dichotomous theory of memory can be summarised as follows:

1. Rapid forgetting of newly acquired material which is not rehearsed (Hebb 1949, Bower 1967).

2. Rapid forgetting is time dependent; over longer periods forgetting is material dependent (i.e. trace decay causes forgetting in the short term, interference in the long term)(Broadbent 1963, Peterson 1966).

3. The limited capacity of short term memory to store recent

information (Adams 1967).

4. Different interference and coding effects over time, i.e. STM is subject to acoustic interference and LTM to semantic interference and coding effects only (Adams 1967, Wickelgren 1969a, Norman 1968, 1969).

5. The differential effects of rate of presentation, duration of presentation, delay, etc. upon differing sections of the serial position curve (Peterson 1966b, Glanzer and Cunitz 1966, Waugh and Norman 1965, Tulving 1968 amongst others).

6. Reminiscence effects indicate a switch from one retrieval mechanism to another (Peterson 1966c, Tulving 1968).

7. Recency mechanisms are indicated by avoidance of responses recently given (Peterson 1966a).

8. Rapid forgetting of newly acquired information following ECS and other shock (Weiskrantz 1967, Bower 1967).

9. Physiological insult to the hippocampus, resulting in rapid forgetting of newly acquired information, but no damage to older pre insult memory. (Wickelgren 1968, Atkinson and Shiffrin 1968, Adams 1967)

10. The effects of Protein synthesis inhibitors on Memory (Deutsch 1969).

11. Introspective evidence of a rapidly disappearing "echo box" (Waugh and Norman 1965, Norman 1968.)

CHAPTER 3

SOME SUPPORTERS OF A SINGLE SYSTEM THEORY

Whilst a number of theorists have expressed doubts over the interpretation of memory data as indicative of two dichotomous memory systems (e.g. Galanter (1967), Keppel (1968b), Loess (1968), Deutsch (1969), Postman (1964) and Melton (1963)), the two major attacks on the dichotomous theory of memory have come from Postman (1964) and better known, perhaps, Melton (1963). These are now considered.

Melton's Theoretical Position

Melton's theoretical position is stated in a number of places (1963, 1964, 1967) and is not entirely free from contradiction. Indeed in 1967 he states - p 91 - that very short term memory might last up to 15 seconds, and might have unique characteristics. In the light of the theoretical statements of Wickelgren (1969a) of Broadbent (1963) and others, a period of up to 15 seconds is clearly within the domain of short, post categorisation memory, and not very short term memory which is taken to last up to about 1 second only. To allow that memory can have unique characteristics up to 15 seconds after intake of information is, in the view of this writer, a collapse of the theoretical position that STM and LTM are on a continuum.

Despite possible reservations about Melton's theoretical position, his attempt to attribute to short and long term memory a universal cause of forgetting - interference, and to dispense with a dichotomous interpretation of the data, has been most influential and few papers on the topic fail to note that due to his work the question of whether one should talk of one memory system or two is still in doubt (e.g. Murdock 1967).

The principal questions that Melton addresses himself to are these:

1. Does STM involve activity traces, whereas LTM involves "structural" traces, as suggested for instance by Hebb (1949).
2. Does STM involve autonomous trace decay, whilst LTM involves irreversible, non-decaying traces, as Hebb has also suggested, and
3. Does STM have a fixed capacity that is subject to overload and consequent loss of elements stored in it for non-associative reasons, whilst LTM is infinitely expandable with failure to retrieve attributable mainly to incompleteness of the cue to retrieval, or to interference effects.

In posing the question of a single system thory or a duplexity theory in these terms, Melton is clearly replying to dichotomous theories based on various assumptions made by Hebb (1949). However many psychologists have allowed that Hebb's formulation is invalid in respect to one or more of the points made above, but still hold a dichotomous theory. Wickelgren (1969a) for instance, holds that forgetting in STM is due to associative factors, Adams (1967) holds that interference is the cause of forgetting in STM, and Tulving (1968) holds that all material enters the same storage system, and that differences between STM and LTM lie in trace utilisation not in the nature of the trace laid down. Whatever answers that Melton gives, therefore, cannot be taken as overthrowing a dichotomous theory of memory, without taking these later theoretical positions into account.

It must be admitted, however, that many theoretical formulations do make the assumptions that Melton wishes to attack (e.g. Broadbent 1963).; indeed Melton (1963) considers that the decay of traces in immediate memory, compared to the irreversability of traces established through repetitive learning, is the most universally acclaimed differentiation.

Melton's attack on a dichotomous theory involves trying to show that associative interference accounts for forgetting in short term memory as it is assumed to in long term memory. The term "interference" as used by Melton differs from the usage of the term by psychologists such as Waugh and Norman (1965) and Wickelgren (1969b), in that Melton uses the term to indicate that all instances of failure to retrieve are not instances of erasure of traces. Thus 1967, P 54 "Interference theory, as applied to LTM has no permanent erasive component." later - P 228 - Melton makes it clear that interference works at the time of retrieval, and also contains a temporary unlearning component, according to his view of interference theory. As he claims that the competition at response is the classical theoretical formulation, (it is the formulation of McGeoch (1942)) it does seem unnecessarily confusing that different writers should use the term with such different meanings. (Waugh and Norman for instance appear to regard interference theory as a form of displacement theory - P 89 "Is its physiological trace in some sense written over by the traces of the items that follow it?")

The point is not merely pedantic. As Melton (1963) himself points out, classical interference theory implicitly accepts a one mechanism theory of memory. Its extension to forgetting over the short term, therefore, makes it impossible to hold a dichotomous theory of memory. For writers such as Adams (1967) to claim that interference governs forgetting over both the short and the long term, and still maintain a dichotomy is therefore at worst paradoxical, and at best misleading.[/]

The evidence that Melton brings to bear on the question of whether or not rapid forgetting is due to interference comes from the papers of Peterson and Peterson (1959), Murdock (1961) Keppel and Underwood (1962) and his own evidence. A consideration of the evidence leads him to the conclusion that trace decay is not a major factor in short term forgetting. Thus he points out that single consonants are remembered with very high frequency over a 32 second interval filled with disruptive activity, and secondly that intra unit interference accounts for forgetting, rather than time per se. (Increasing the number of consonants shows an orderly decrease in retention.) The evidence of Keppel and Underwood (1962), too, is strongly suggestive of PI effects in short term memory experiments and hence the effect of previous similar material on the time course of forgetting.

The other line of evidence which Melton considers, is based on repetition effects. The most cogent argument put forward is based on an experiment of Hebb (1961) replicated by Melton, which shows that even with a large number of items interpolated between one presentation and its repetition, there is evidence of a repetition effect. In Melton's replication experiment, 8 sequences of 9 digit numbers were interpolated

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[/] Footnote: For a fuller discussion of this point, see Chapter 6.

between presentation and repetition, and Melton remarks - P 18 - "Surely the structural memory trace established by a single occurence of an event must be extraordinarily persistent." Again Melton is further persuaded by the orderly way in which repetition operated in both sub span and supra span units to increase the probability of retrieval, that the STM LTM distinction is unwaranted.

Postman's theoretical position

Postman's (1964) criticism of a dichotomous theory may be considered under two main headings: 1. The limitation on our capacity for immediate reproduction of materials. 2. The mechanisms of rapid forgetting.

In considering the capacity of immediate memory, and in particular, the memory span, Postman notes that it is not the transmission of information per se which is limited; it is the number of items, and that the limitation may be due to such factors as Proactive Inhibition, which also operate in long term memory.

As with Melton, Postman (1964) sees the nature of short term forgetting as central to a resolution of the problem of a dichotomy or a continuity of memory systems. Again, like Melton it is Hebb's theory which is considered and the notion of autonomous trace decay that is attacked. Postman notes that the concept of the decaying memory trace derives most of its face validity from the extreme rapidity of forgetting of unrehearsed material and that rehearsal is claimed to prevent the trace decaying.

Postman raises two objections to the interpretation of this type of data in terms of two memory systems. In the first place he notes evidence which suggests that interpolated material, and not time is responsible for forgetting, and perhaps more importantly, he notes that results of immediate memory experiments and those of long term memory experiments, upon which conclusions concerning a dichotomy are drawn, are not sufficiently comparable to make a judgment about the relative rates of forgetting in the two situations (a point echoed by Keppel (1965) and Goggin (1966)).

Postman points particularly to the difficulty, if not the impossibility, of a true test of trace decay in immediate memory experiments. Even unrelated interpolated material may have interfering properties of a retro-active kind, and in LTM (rote learning studies) such effects have been found even where inter item similarity is low.

Summary of Melton's and Postman's Position

Both Melton and Postman, then, are concerned to attack a dichotomous theory of memory in which STM forgetting is conceived of as being due to autonomous trace decay, and LTM forgetting is considered due to (classical) interference. Rehearsal is seen as a means of transferring material from short to long term memory and the two systems are not conceived of as overlapping, temporally. Evidence of retention following a single exposure is taken as evidence that a structural trace results from a single exposure. In that both Postman and Melton were concerned with a Hebbian theory, their attacks on a dichotomous theory are not able to take account of later formulations. To say all this is not to be taken as critical of their important work in this area of memory. On the contrary, claims that Melton and Postman have not brought down a dichotomous theory of memory (e.g. by Waugh and Norman (1965)) must be set in the context of dichotomous theories as they then were at the time the papers were written. What must be made plain however, is that the work of Melton and Postman is not enough: more recent developments must be taken account of. Moreover, perhaps one major criticism can be levelled at both Melton and Postman. Neither has faced up to the problems posed for a single system theory by physiological evidence, e.g. of the type produced by Milner (1959), and upon which many dichotomists rest their case, e.g. Wickelgren (1968) Atkinson and Shiffrin (1968), that physiological insult involves a failure to retain recent information, whilst leaving previously learned material unaffected.

Other considerations

Finally, no chapter on evidence for a single system theory would be complete without reference to the work of Hebb (1961). Hebb, it will be remembered, is responsible for stating the dichotomous position from which most present day argument has emerged. Yet as a result of work on repetition of digit sequences, he changed his position, at least to the extent of allowing that a single repetition of a set of digits produces a structural trace which can be cumulative. The actual experimental procedure, which as was noted, was more or less replicated by Melton, involved presenting a series of digits, followed by an interpolation of a number of digit sequences, followed by a second presentation of the original sequence. Saving on learning occurred even though there was no recognition.

CHAPTER 4

SOME THEORETICAL ISSUES

The two previous chapters described the theoretical positions of those maintaining a dichotomous and a single system theory of memory, and outlined the basic empirical evidence which led to such positions. This chapter will look in general terms at some of the problems raised in holding a dichotomous theory of memory. Specifically it will pose the question as to what evidence is necessary in order to hold a dichotomous theory; it will examine the means by which such evidence for a dichotomy is gathered and will aim to show that these means preclude the possibility of proving a dichotomous theory of memory.

The basic criterion for distinguishing short and long term memory

As Hilgard and Bower (1966) note, the question of whether one should maintain a single system or duplex system theory of memory ultimately rests on the question of the nature of rapid forgetting. They consider a possible resolution of the problem to rest on the question of whether rapid forgetting is due to autonomous trace decay or to interference, clearly a response to the dichotomous formulations of Hebb and Broadbent. Yet as a review of dichotomous theories in Chapter 2 clearly showed, many formulations do not insist on autonomous trace decay as the cause of forgetting in short term memory, and indeed some, e.g. Wickelgren (1969 a) and Adams (1967) actively deny it, and use evidence which at first sight seems unrelated to the question of the cause of rapid forgetting, to claim a dichotomous theory. Thus Adams suggests that the limit in capacity to recall recent information, and differences in interference effects as between short and long term memory, are grounds for holding a dichotomy. Why then, is rapid forgetting the basic criterion upon which all the evidence for a dichotomous theory of memory rests? In order to answer this question it is necessary to consider the means by which inferences on memory states are drawn.

Investigation of memory processes involves presentation of material under controlled conditions, and investigating the effect of an independent variable on retention. Those interested in differences in memory processes over time, clearly, therefore, wish to investigate any differential effects that an independent variable may have over time. In the nature of the subject matter under investigation any difference attributable to an independent variable must involve either forgetting or some addition to material originally presented. If no forgetting occurred either immediately or after a period of time, then every item originally presented would be recallable at any point in time. In such a case no inferences could be made regarding different mechanisms underlying memory in the short and the long term, unless of course qualitative additions were made to each item.

Of course forgetting does occur, and differences in the time course of forgetting are of necessity used to draw inferences regarding underlying memory mechanisms. This necessity is brought about because no qualitative additions i.e. associative differences, have yet been shown over time. It must be admitted that one, semantic association, has been suggested (by Adams 1967, Baddeley 1968) but Gruneberg and Sykes (1969a) have noted only some of the many studies indicating semantic processing in STM. Indeed, as they point out, that the words before one as one reads, are meaningful, indicates immediate semantic processing.

Evidence, then of qualitative differences over time in the nature of memory came from studies indicating quantitative differences in forgetting rates over time as a result of experimental manipulation. For instance to measure the effects of repetition on short and long term memory, one obtains a measure of the effect of repetition on forgetting in what is considered short term memory (i.e. measuring differences in the forgetting rates of materials which have, and have not, been subject to repetition) and comparing this with a measure of the effect of repetition on forgetting in what is considered to be long term memory, (again by measuring differences in forgetting rates of materials which have and have not been subject to repetition). Effectively then, the effect of repetition on rapid and less rapid forgetting is measured, and perhaps the inference drawn is that rapid and less rapid forgetting react differently to repetition; the inference of those holding a dichotomous theory of memory being that such different reactions are based on different underlying systems of memory.

All the lines of evidence produced to support a dichotomous theory of memory, are in fact based on the assumption that rapid forgetting distinguishes material in the two purported systems i.e. that material which is rapidly forgotten has been lost from STM whereas material which is less rapidly forgotten has been lost from LTM. The lines of evidence produced to support a dichotomous theory which are listed in Chapter 2 will now be examined in order to illustrate this.*

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* Footnote: Actual criticism of the lines of evidence will be postponed to later chapters.

Rapid forgetting and the empirical evidence

The first two lines of evidence, the phenomenon of rapid forgetting of newly acquired material and the claim that differences between rapid and less rapid forgetting are in terms of autonomous trace decay for the former and interference for the latter, clearly depend on the assumption that rapidly forgotten material is lost from STM, and needs no further elaboration.

Point 3, evidence of the limited capacity of subjects to hold material for recall, compared to the relatively unlimited capacity to retrieve well learned material, might at first sight not appear to depend on rapid forgetting differentiating the two systems, and indeed Adams (1967), who puts this line of evidence forward as indicative of a dichotomy of memory systems, claims that rapid forgetting is not a characteristic of short term memory per se. Yet, as Adams admits, the usual means by which it is claimed short term memory is limited involves the use of the immediate memory span in order to assess what the capacity of immediate memory is. The memory span is obtained by assessing the number of items in a sequence which a subject can correctly reproduce following a single exposure. Typically a subject will be able to recall 7 - 9 items successfully. Where more than this number of items are presented, rapid forgetttting takes place such that the sequence cannot be successfully reproduced. It is at the point at which rapid forgetting of supra-span items sets in that the memory span is therefore defined. Most important of all, however, the memory span items are considered to evidence the capacity of short term memory because they are themselves rapidly forgotten in the absence of rehearsal, as many psychologists e.g. Hunter (1964) point out. Clearly rapid supra-span and rapid memory span forgetting together are responsible for assuming that the immediate memory span defines the capacity of short term memory. Thus the limited capacity hypothesis is ultimately dependent on the assumption that short and long term memory can be distinguished on the basis of rapid forgetting. This may be stated alternatively. If rapid forgetting cannot be taken to distinguish short and long term memory then the immediate memory span cannot be taken as indicative of a characteristic of short term memory.

It might be argued that supra span forgetting is due to failure to take information in (registration) rather than to rapid forgetting. Yet certain evidence is against this interpretation; thus merely adding a single digit 0 at the end of a sequence severely hampers recall of the rest of the sequence (Conrad 1960). In fact scores in his subjects were reduced from 73% to 38%. Forgetting here was clearly demonstrated and it is therefore reasonable to suppose, as Conrad's experiment in many ways ressembles going from a sub to supra span series, that the effect of adding digits over the memory span is to induce forgetting. Again, subjects can always tell, of a sequence of digits say, that items are digits, and not letters, an impossibility unless each item had been acquired and categorised.

The next line of evidence considered, differing coding system systems as between short and long term memory, also put forward by Adams (1967) amongst others, rests on the demonstration that acoustic confusion, i.e. confusion amongst items which sound alike, is confined to the short term whereas items with similar meanings were confused in the long term. The evidence upon which Adams rests his case, basically, are the experiments of Baddeley (1966 b) who claimed to show that acoustically similar lists were subject to marked interference effects over the <u>short term only</u>, whereas semantically similar lists were subject to interference over the <u>long term only</u>. Again at first sight it is not evident that inferences based upon this type of data rest ultimately on the assumption that rapid forgetting distinguishes the two systems. However, for interference effects to show themselves, forgetting must have taken place, and to regard STM as being susceptible to acoustic interference is to allow that in STM rapid forgetting has taken place of such a nature asto allow confusions of acoustic aspects of stimuli to take place. On the other hand to confine semantic interference to long term memory is to claim that slow forgetting i.e. forgetting which manifests itself only some time after the intake of information, is of such a nature that semantic aspects of items are confused. Clearly if rapid forgetting of semantically related material occurred, its effects would be manifest shortly after the intake of material and semantic confusion would be attributable to short term memory. Thus again, the assumption that rapid forgetting distinguishes the two memory systems is seen to be operating in this experimental situation.

The next line of evidence, noted in Chapter 2, concerns evidence for a dichotomous theory of memory based on free recall studies of the serial position curve, in particular, the fact that different sections of the serial position curve 'react' differently to different variables. For example the early and middle sections of the serial position curve are affected by rate of presentation of items, whereas the last part of the curve is not. In order to see that this evidence ultimately depends on rapid forgetting distinguishing the two systems it is necessary to consider what the experimenter and subject are doing in a typical free recall, serial position experiment. Typically, subjects are presented with a list of items above the memory span, and are requested to recall as many items as they can, immediately the presentation is finished. The items are then plotted according to their probability of recall, for each position on the presentation list. A second list of items is then presented, in which some variation in presentation rate, nature of material etc. is present, and a second serial position curve is plotted. Differences between the two serial position curves are then examined, normally comparing the effects of the independent variable on the beginning and middle sections, and the end section of the curve.

Two points of particular importance should be noted. The earlier the item on the serial position curve, the longer it has to be retained from presentation to recall, and the larger the number of items interpolated between presentation and recall. Whilst something of an over-simplification, the serial position curve is therefore in a sense a form of normal forgetting curve, in which one compares forgetting immediately after presentation with forgetting after a period of time between presentation and recall. With the forgetting curve one expects normally that retention immediately after or soon after presentation to be high, but dropping off steeply until the curve levels out. This is also present in the serial position curve where the most recently presented items are best retained, but where the probability of retention drops steeply the older the item, until there is a levelling off in the probability of forgetting. Hence any difference between the earlier and later part of the serial position curve is due to differences in forgetting rates, with rapid forgetting being characteristic of the recency part of the curve. The effect of variables on the serial position curve is therefore to change the course and extent of rapid forgetting, and the assumption that the recency part of the curve indicates output basically from STM is based therefore on the assumption that rapid forgetting is characteristic of STM, but not LTM.[ø]

Perhaps two examples will help to illustrate the points being made. Glanzer and Cunitz (1966) carried out two experiments in which the shape of the serial position curve was examined in relation to two independent variables. In one experiment this variable was time between presentation and recall, the intervals being zero seconds, 10 seconds and 30 seconds. In the latter two conditions there was an interpolated activity between presentation and recall. The result of interpolation of activity between presentation and recall was a reduction of the recall probabilities of the last few items, whilst the earlier items were unaffected. Glanzer and Cunitz claimed that this indicated that STM but not LTM was affected by interpolation of activity. Whether this is so or not will be considered in a later chapter, at present it is only necessary to note that the immediate recall condition is testing recall before the most recently presented items have gone through their period of steepest decline i.e. early in the forgetting curve. After a delay of 30 seconds or so they will have had this opportunity and one would not expect the most recently

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ø Footnote: A number of studies using paired associate techniques have been used by for example Peterson (1966 a) to support a dichotomous theory. These studies have shown the differential effects of independant variables, on the first and later sections of the forgetting curve. Apart from providing empirical support for free recall studies, it reinforces what has been said about serial position curves being an alternative form of presentation of this kind of data, to forgetting curves.

presented items to have such high recall probabilities as previously. In other words one is merely examining the course of rapid forgetting, and in attributing this rapid forgetting to STM Glanzer and Cunitz are clearly using it as a criterion for distinguishing STM and LTM. It is reasonable to point out at this stage that the conclusion, that rapid forgetting of the recency section of the curve indicates output from STM, is to admit that rapid forgetting is the criterion by which one decides that material is characteristic of STM. Thus if items in the first part of the serial position curve had somehow (mysteriously) been forgotten as a result of interpolation of activity, leaving the end part of the serial position curve unaltered, then the end part of the curve would be taken as indicating basically output from long term memory, LTM not being susceptible to rapid forgetting i.e. being a stable memory system (Murdock 1967).

The second experiment carried out by Glanzer and Cunitz showed that presentation rate affected the earlier and middle but not the last part of the serial position curve. In their experiments the rates of presentation of items varied from one every three to one every nine seconds. Clearly even at the fastest rate of presentation the opportunity for rehearsal was present. As numerous studies have shown the greater the opportunity for rehearsal or control processes, the greater is retention, and clearly as rate of presentation increases, so do opportunities for control processes decrease. One can therefore interpret the serial position curves of this type of experiment in terms of control processes affecting the extent but not the rate, of rapid forgetting. Again rapid forgetting must be assumed to be the criterion which distinguishes short from long term memory if the recency part of the curve is to be interpreted in terms of output from short term memory.*

The next line of evidence noted in Chapter 2 (point 6) reminiscence effects, indicates, according to Peterson (1966 c), a switching from one retrieval system to another. The experimental evidence consists of showing that material which is rapidly forgotten i.e. unavailable to immediate recall, can in fact be recalled more efficiently after a period of time. Thus again, rapid forgetting is assumed to distinguish material in "STM" and "LTM".

The seventh line of evidence noted, is based on evidence of avoidance of responses recently given and therefore known to be wrong in an experiment in which responses given some time previously are not avoided. This can again be attributed to rapid forgetting. As one is able to retain information recently given for a short period of time one is able to avoid a response recently given and known to be wrong. On the other hand becuase of rapid forgetting only the most recently given material will be available to aid in such a task. Rapid forgetting again underlies this operational distinction between short and long term memory.

The next lines of evidence, Points 8, 9 and 10 are those based on the effects of shock of physiological insult. In all cases information recently acquired is rapidly lost and inferences are based on this rapid forgetting of such a nature that it is assumed rapid forgetting indicates loss ofrom STM.

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* The whole question of the serial position curve and its relevance to the present controversy will be dealt with in Chapter 9.

The introspective evidence, put forward by Waugh and Norman (1965), Point 11, appeals to introspective evidence of rapid forgetting and needs no further elaboration. As a statement of the phenomenon of rapid forgetting its value as a source of evidence for a dichotomy stands or falls on the question of whether rapid and less rapid forgetting have the same cause.

The purpose, then, of this analysis of the lines of evidence put forward in Chapter 2 in support of a dichotomous theory was to indicate that all those lines of evidence depend on the assumption that short and long term memory can be distinguished by attributing to short term memory rapid forgetting or its operational consequences, and by attributing long term retention or less rapid forgetting to long term memory. If rapid forgetting takes place in long term memory then all the empirical evidence for a dichotomous theory is questioned because it becomes impossible to decide, of any operation which results in rapid forgetting, in which system it should be considered.ø

The evidence required to establish a Dichotomous Theory

Many theorists do in fact accept that the critical question is whether rapid and less rapid forgetting have the same underlying cause in which case rapid forgetting can be assumed to take place in the same system as less rapid forgetting. (e.g. Melton 1963, Hilgard and Bower 1966). The previous analysis of evidence for a dichotomous theory

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ø As the writer has noted elsewhere (Gruneberg 1969 a) "To argue that relatively stable retention is only a sufficient condition for LTM entails the possibility that all material enters LTM direct and makes any measurement of operational differences between STM and LTM impossible."

indicated that those psychologists who claimed that rapid forgetting was not a characteristic of STM per se e.g. Adams (1967) were inconsistent and in fact made this assumption when putting forward evidence of a dichotomy.

The present writer would like to take the points raised by Hilgard and Bower, by Melton and by others, a stage further.

Hilgard and Bower, for instance, concentrate on the question of whether autonomous trace decay of interference cause forgetting over the short term, it being accepted by many dichotomists e.g. Broadbent (1963) that interference causes forgetting in long term memory. Many arguments are put forward to support the possibility of autonomous trace decay as the cause of short term forgetting, including some which are required to overcome the problems posed for autonomous trace decay by evidence that similarity of items affects forgetting in the short term, and so on. They do not consider whether some of these arguments could be used to support the view that forgetting over longer periods might be due to autonomous trace decay, a view that is certainly held by some psychologists (e.g. Brown 1958). In view of what has been said, it is not enough to establish the cause of forgetting in the short term; it must be shown to be qualitatively different from forgetting in the long term if a duplexity theory is to have currency. Indeed the question of the actual cause of forgetting is not crucial to those holding a single system theory. They can accept forgetting as being due to any cause, be it autonomous trace decay, "classical" interference, displacement, compression or whatever. The critical issue is whether there is any evidence which shows that whatever the cause of forgetting is, over the short term, is not the cause of forgetting over the long term.

Whilst the actual cause of forgetting is not critical for those holding a single system theory, the question as to the cause of forgetting is relevant to the issue of one memory system or two because certain theories of forgetting imply, as Melton (1963) notes, a single system theory. This is particularly true of interference theory in its classical form, in which forgetting is claimed to be due to factors other than storage loss (e.g. competition at time of response). (Psychologists such as Adams who look upon STM forgetting as being due to interference, and at the same time hold STM to have limited storage capacity are using "interference" in a misleading way. As was pointed out previously, they are not talking of interference in the same way as other psychologists [Indeed Adams uses interference in a way which is probably indistinguishable from trace decay]). To hold a classical interference theory position is incompatible with a limited storage capacity hypothesis, in that interference theory claims that once in store, material is forgotten for reasons other than loss from store - a hypothesis that is contradictory to the limited storage capacity hypothesis.

Whilst a failure to resolve the question of the exact nature of short or long term forgetting is not critical to a resolution of the problem in favour of a single system theory of memory, a failure to resolve the problem of the nature of short term forgetting is in fact <u>fatal</u> for a dichotomous theory of memory. This is because a failure to show that short term forgetting is qualitatively different from long term forgetting must lead to the abandoning of a dichotomous theory in favour of a single system theory on the grounds of parsimony, a single system explanation being more parsimonious than a dichotomous theory interpretation, other things being equal. In other words, if it cannot be shown that short term forgetting is not due to "classical" interference (assuming interference is the cause of forgetting in LTM) than a single system theory must be held as only one explanatory principle is involved rather than two. It is not necessary to show that only a single system theory can handle the data, it is necessary only to show that it can handle the data as well as a dichotomous theory, in order to force an abandonment of a dichotomous theory.

Single system theory explanations of the empirical data

If one holds a single system theory one is of course faced with the problem of explaining rapid forgetting. A single system explanation is in terms of differing susceptibility of materials to those factors which universally cause forgetting, rather than differences in underlying memory mechanisms. As Wickelgren (1965 a) puts it P53. "On the contrary, if interference in STM can be shown to depend on the nature of the interfering adtivity in the same way as in LTM, then it will be plausible to assume that STM and LTM are performed by the same system operating in a quantitatively different manner under different degrees of learning." Rather than different degrees of learning, this writer prefers to talk in terms of differing susceptibility to forgetting. Differences in susceptibility may have various causes. Thus for example, items in the middle and end of any sequence are likely to be more susceptible to pro-active and inter item interference merely due to their position within a sequence; again if interference or autonomous trace decay causes retention failure through failure to discriminate similar aspects of stimuli, as some psychologists have suggested (e.g. Conrad 1967), then differences in forgetting rates can be attributed to the relationship between the new item and the existing cognitive framework. Those items which are unique, yet related to other items in the cognitive framework one would expect to be forgotten less rapidly because they would be less subject to interference and retrieval difficulties. Again, repetition of an item to the point of learning may make an item immune from rapid forgetting factors because the strength of the item is above a point at which it is liable to gross interference factors, as Corballis (1966) suggests. Newly acquired items may be unduly susceptible to interference because they have not been fully integrated within the memory system and hence be unduly susceptible to forgetting factors. Differences in susceptibility of differing materials to rapid forgetting e.g. acoustic as opposed to semantically related materials, may again merely reflect the higher susceptibility of acoustically related materials to those factors which universally cause forgetting. This may be because acoustic relationships, being much less frequently used than semantic relationships, are less well integrated within the memory system and hence much more liable to those factors which universally cause forgetting.

A dichotomous theory - unproved and unprovable?

If it is always possible to claim that rapid forgetting can be accounted for in terms of differing susceptibility of materials to those factors which universally cause forgetting, if, as the next chapter illustrates, it is not possible to claim that rapid forgetting is due to autonomous trace decay, displacement, compression or whatever, as opposed to some other form of forgetting in LTM; if as subsequent chapters hope to show, all the evidence considered in Chapter 2 is either defective or another way of posing the question as to the cause of rapid forgetting rather than answering it, then a dichotomous theory is unprovable and unproved. It is unprovable if there are no empirical means of distinguishing the possibilities of two memory mechanisms and one mechanism in which rapid forgetting is attributable to differences in susceptibility of materials to forgetting, and if it is empirically impossible to separate interference and other forgetting factors.[/]

It is unproved if no evidence unequivocally supports a dichotomy, even allowing that rapid forgetting can be used as a criterion for distinguishing material in the two systems.

As was previously pointed out, to hold a single system theory it is not necessary to show that the data can only be handled by a single system theory, it is enough to show that it can be handled by a single system theory. In other words it is enough to show that no evidence unequivocally supports a dichotomous theory, in order to hold the more parsimonious single system theory. The single system theory is more parsimonious despite postulating differing susceptibilities of materials to those factors which universally cause forgetting because a dual system theory must in fact do the same, as well as postulating two memory systems rather than one. If material in long term memory did not differ in its susceptibility to forgetting, then all material of the same strength, once in LTM, would be forgotten at the same rate. Yet

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/ Footnote: It is certainly unprovable if one allows, as Adams (1967) does, that interference operates in both STM and LTM. It is clearly impossible to separate two systems theories from those which advocate differing susceptibility of materials to those factors which universally cause interference.

various experiments e.g. by Baddeley (1966 a) indicate that semantically related material is forgotten at a faster rate in LTM than non-semantically related material, clear evidence of differences in forgetting rates for different materials in LTM. If therefore, one is not going to postulate different underlying mechanisms to account for different forgetting rates, one must account for the phenomena in terms of differing susceptibility to factors which universally cause forgetting, and hence create a more unparsimonious theory than a single system (not a single process) theory.

It might of course be argued that parsimony is something which a scientist need not accept. In the view of this writer this is quite wrong. Parsimony is the scientific principle. Given enough post hoc assumptions almost any theory can be justified, but the most economical theory is held until it is shown to be the less economical; the confusion of some writers e.g. Atkinson and Shiffrin on the question of parsimony is one of confusion of economy, of systems and economy of explanation. Of course a single system theory of memory may be less parsimonious than a dichotomous theory if the maintenance of a single system theory requires the postulation of more general principles than the maintenance of a dichotomous theory. If, however, a single system theory requires the postulation of a lesser number of general principles, than it is more parsimonious, and this is the position taken by the present writer. If it is never possible to distinguish between an explanation based on two systems and one based on differing susceptibility to forgetting of materials within one system, then the necessary addition of a further explanatory principle for a dichotomous theory in terms of differing susceptibility of materials to forgetting in one of the systems makes it less parsimonious in a real sense. This is because a single system theory and a dichotomous theory hold the single system theory principle in common, and a dichotomous theory adds an additional principle.

Summary of Chapter 4

This chapter has looked at the criterion upon which evidence for a dichotomous theory is based. All the lines of evidence noted in the previous chapter were examined in order to demonstrate that they depend on the assumption that rapidly forgotten material is lost from short term memory, and that long term memory is a relatively stable system.

The critical question can thus be seen to be the cause of rapid forgetting. Has it the same or a different cause from long term forgetting? It was pointed out that for the purposes of maintaining a single system theory it was not necessary to specify the cause of rapid forgetting. It is sufficient to show that there is no reason to suppose that the cause of rapid and less rapid forgetting differs, whatever the cause. Yet to hold a dichotomous theory it is necessary to show that certain theories cannot account for rapid forgetting in that they are incompatible with a duplexity theory.

It was next noted that if one holds a single system theory one is faced with explaining the phenomenon of rapid forgetting. Basically a single system theory accounts for rapid forgetting in terms of greater susceptibility of materials to those factors which universally cause forgetting. As it seems to the writer empirically impossible to distinguish a two system theory in which rapid forgetting has a different cause from less rapid forgetting, and a single system theory which accounts for rapid forgetting in terms of differential susceptibility of materials to those factors which universally cause forgetting, then a dichotomous theory of memory is unprovable . This is also true if different causes cannot be attributed to rapid and less rapid forgetting, in which case, of course, rapid forgetting must be accounted for in terms of differing susceptibility of materials to those factors which universally cause forgetting.

Not to be able to establish a dichotomous theory is to force its abandonment in favour of a single system theory, because of considerations of parsimony. This is because a duplexity theory must apply in explanations of long term forgetting, the principle of differing susceptibility of materials to those factors which universally cause forgetting, in addition to the principle of two memory systems.

CHAPTER 5

RECOGNITION AND RECALL

There are two reasons for considering the relationship between recognition and recall at this point. First, it has methodological implications in that recognition experiments are often taken to have relevance for findings based on recall experiments, e.g. Adams (1967), as previously noted, uses Hebb and Foord's (1945) experiment employing a recognition task, to dismiss the autonomous trace transformation theory of the Gestaltists, whose findings were often based on recall experiments. Second, and more important perhaps, if recognition and recall are dichotomous states, then there exists the possibility of four memory systems over time, rather than two i.e. a short term and long term recognition memory, and a short term and long term recall memory.

In this chapter an analysis of the relationship between recognition and recall will commence with a consideration of the nature of recognition and recall tasks. There will then follow an analysis of the various positions taken by writers on the relationship between recognition and recall. The first hypothesis considered is that recognition and recall involve dichotomous storage systems.

The next hypothesis to be considered is that recognition and recall involve dichotomous retrieval systems as Kintsch (1968) for instance , has suggested. It will be argued that this is not a necessary conclusion on the basis of available evidence.

If recognition and recall tasks are not indicative of dichotomous states, then the question of the exact relationship still remains. It is suggested that recognition scores do indicate greater storage than do recall scores, whatever the relationship between recognition and recall, and it is further suggested that the relationship between recognition and recall involves forgetting rather than partial acquisition at least under normal circumstances.

The nature of recognition and recall tasks.

The recognition test takes two basic forms. In one form (multiple choice testing) the correct item is embedded in a number of false alternatives (distractors) and the subjects are required to select the correct item. The forced choice techniques employed by Shepard (1967) in which only one distractor was present, is a special case of this technique.

The second form which the recognition test takes is to present an item without a distractor, and ask whether the item is new or old, new and old items being mixed in the retention test. (This form of the recognition test is used by the writer as it overcomes many of the difficulties of interpretation involved in the multiple choice test, such as the effect of identifying incorrect responses on retention scores((See Chapter 7).

Recall tests on the other hand, involve the presentation of material, and a request for the reproduction of that material without any further cues from the experimenter which might aid retrieval. This is the essential difference between recall and all recognition tests, whether single item or multiple choice. The recognition tasks both involve presenting the subject with the ultimate cue for retrieval - the original item.

When one considers the literature on the relationship between recognition and recall, it is soon clear that there is as much disagreement amongst students of memory in this area as on the question of the relationship between short and long term memory, and this disagreement crosses the theoretical boundaries of single system as opposed to dichotomous system formulations on short and long term memory. Thus both Tulving (1968) and Adams (1967) who are dichotomous theorists maintain that recognition and recall are dichotomous states, whereas Shiffrin and Atkinson (1969) and Bower (1967), also dichotomous theorists, take the opposing view.

Whilst Tulving (1968) - P 27 - states "Scores on a recognition test are determined by different retained information from that measured by recall tests.", others, such as Norman and Wickelgren (1969) prefer to back up their assertions with empirical evidence. The relevant paragraphs (P 195) are quoted in full.

"There is actually considerable evidence to support the assumption that the same memory system is employed in both recognition and recall, though there is really no evidence on the relation between the memory system used in recognition and that used in multiple choice tests of STM.

"Qualitative support for the assumption of a common memory system for both recognition and recall is provided by experiments showing that errors in STM tend to be phonetically similar to the correct item for both recall (Conrad, 1964, Wickelgren 1965a, 1965 b, 1966) and recognition, Wickelgren (1966), and that repetition, primacy and recency affect recall and recognition tests of STM in similar ways. Quantitative support for the assumption of a common memory system for recognition and recall is provided in a study by Norman (1966) which compared the rates of decay for the two types of tests, using strength theory to transform response probabilities into trace strengths in both cases. The rate of decay in verbal STM was quite similar for both recall and recognition."

Despite the claims put forward by Norman and Wickelgren (1969) and by Tulving (1968) there is evidence which poses problems for those holding both a common memory system and a dichotomous memory system for recognition and recall.

Recognition and Recall: Dichotomous storage systems.

Adams (1967) considers the hypothesis that recall and recognition are based on a common memory trace but that recognition has a lower threshold and is more sensitive, and concludes that there is little empirical support for this position. He claims that the hypothesis is based on the findings that recognition tests yield higher retention scores than do tests employing recall. Such findings are frequently reported in the literature e.g. Postman et al (1948), Kay and Skemp (1956) and also confirmed in Experiment 1 of this thesis (Chapter 7). Adams attacks this position however, by an appeal to such findings, as those of Davis, Sutherland and Judd (1961), who showed that increasing the number of alternatives reduced recognition, and Bahrick and Bahrick (1964) who showed that reducing the discriminability of items reduced recognition, in multiple choice recognition tests.

On P 267, Adams notes: "There remains the uncomfortable fact that recognition is not so superior to recall when the number of alternatives in the recognition test is large or the discriminability of alternatives is low." Why this should be an uncomfortable finding is not clear to the writer, as Adams himself earlier notes "that superiority of recognition over recall can be abolished, should not subtract from the very high retention and capacity that can be produced by the recognition method when the number of alternatives is small. Recall can yield nothing like the vast capacity for recognising hundreds of stimuli, as Shepard (1967) has found." Again Davis et al (1961) upon whom Adams' discomfiture rests, are concerned to use their evidence to show that recognition and recall are the same process, not different.

The question that Adams is faced with, then, concerns the reason for the reduction in recognition capability as the number of alternatives or their discriminability increases. Adams treats the number of alternatives and their discriminability as two separate variables, but the evidence of Dale and Baddeley (1962) and of Field and Lachman (1966), is that this is not the case, the similarity of alternatives, not the number, is the critical variable. Common sense too, dictates that this is the case. If a subject is presented with a recognition task of this nature: <u>Presentation item</u>: "The battle of Hastings was in 1066." <u>Recognition task</u>: "Was the Battle of Hastings in 1066, 1901, 1902, 1903, 1904 --------- 1969, it is clear that increasing the number of alternatives in the range 1904 ------- 1969 is unlikely to affect recognition. One possibility is that increasing the number of alternatives, where it does affect recognition scores, does so by increasing interference factors, and indeed Davies, Sutherland and Judd (1961) Field and Lachman (1966) and Teghtsoonian (1965), (who also showed increasing difficulty of recognition with increasing the number of alternatives), suggests this very hypothesis a hypothesis that Adams is certainly aware of. Again Field and Lachman note that one factor in increasing the number of alternatives is an increase in interpolated activity and the retention interval, which can be expected to have a detrimental effect on recognition scores.

There is in fact a great deal of evidence to suggest that recognition rate is dependent on similarity factors, just as recall rate varies with similarity of material, apart from the evidence of Dale and Baddeley (1962) that similarity and not number of alternatives per se is critical in recognition rate. Thus Sachs (1967 a, b) found recognition of synonyms embedded in sentences was very low, and Underwood and Freund (1968) in an experiment similar to that reported in this thesis on acoustic and semantic confusion, found that both acoustic and semantic relationships had a detrimental effect on recognition rate. The experimental evidence of Annisfeld and Knapp (1968) also showed the effects of semantic relationships on recognition scores, and Allen and Gorton (1968) have shown that knowledge of the meanings of rare words facilitates recognition. Again both Gorman (1961) and Shepard (1967) found that frequency of usage of words was related to recognition rate, a finding supported by Young et al (1968), and the evidence quoted by Norman and Wickelgren (1969), noted earlier, supports a similarity interpretation of forgetting for recognition as for recall. Furthermore a study of recognition threshold by Landauer and Freedman (1968) indicates that recognition time increases as category size increases, suggesting that recognition is affected by associative factors. It seems clear, therefore, that the relationship between a word and its previously learned associates, affects recognition rate.

This brief review, then, indicates that recognition, using a small number of alternatives, is superior to recall and that the disappearance of this superiority with increasing the difficulty in discrimination of alternatives, in recognition tasks, can be attributed to an increase in the detrimental effects of similarity on recognition, just as this affects recall. This does not of course indicate that recognition is not less sensitive than recall, merely that tasks can be devised such that this sensitivity is not allowed to operate.

As an alternative to the hypothesis that recognition and recall are based on the same memory system, Adams puts forward a perceptual trace hypothesis, in which it is claimed that exposure to an environmental stimulus establishes an S-perceptual trace of some stability. P. 265: "As far as memory is concerned, the S-perceptual trace is reactivated by the original stimulus at the recognition test and causes the subject to identify it as old. A capability for recalling responses associated with a stimulus need not be present for the identification response to occur, although it may be in some cases. If so the recall of the response is assumed to be based on a different memory state which is being called the "memory trace". " On P 269, Adams elaborates further what he means by the S-perceptual trace, when he talks of an "uncoded image", and differentiates recognition and recall on the grounds of recall involving a response to a stimulus, whereas recognizing does not involve the output of a response.

It has to be said for this theoretical position that it is not disproved by evidence of a correlation between recognition and recall scores for individuals, as Norman and Wickelgren (1969) appear to claim. Thus Adams notes that an S-perceptual trace is the basis for recognition and that a recall trace can be formed at the same time.

Yet there can be little doubt that if he regards recognition as an uncoded image, Adams' theoretical position falls in the face of empirical evidence. In the first place, his formulation in terms of reactivating a perceptual trace with the original stimulus appears to be advocating a template matching process. Von Kreis (1901) points out that such a formulation is incompatible with stimulus generalisation and equivalence, for instance a tune transposed in key. Memory depends on form and pattern constancy and not on the restimulation of the identical stimulus.

Further evidence against the "uncoded image" hypothesis comes from the experiments of Underwood and Freund previously noted, which have demonstrated the effects of semantic and acoustic factors on recognition. The demonstration of acoustic and semantic similarity effects on recognition rate indicates that recognition memory has organisational properties involving acoustic and semantic relationships.

Again the evidence presented by Norman and Wickelgren (1965) must be considered. They found that curves for recognition of single digits and pairs of digits were different. The curves for digit pairs did not follow that of single digits, indicating that some organisation of the digit pairs had taken place, contrary to an "uncoded image" theory.

Other evidence quoted in Norman and Wickelgren's later (1969) paper, and referred to earlier, claims that organisational properties of recognition and recall are similar. They note that repetition, primacy and recency effects act in a similar way in recognition and recall. The evidence here however, is not too clear. Wolf and Jahnke (1968) for instance found that repetition in a series facilitated recognition but degraded recall. Nevertheless, as Wolf and Jahnke admit, the experimental tasks were such that this can be explained without inferring a dichotomy between recognition and recall; the recognition task involved merely identifying an item as having occurred, the recall task depended on retaining both the item and the fact that the item was repeated. It must be pointed out too, that this result is something of an oddity and that repetition normally facilitates recognition as it does recall, e.g. Lachman, Laughery and Field (1966). ≠ 1, ≠ 2

An earlier and related experiment by Melton (1967 b) is also something of a puzzle in that he found that increasing the interval between repetitions <u>de</u>creased recall, but increased recognition. However, this experimental task was exactly opposite to that of Wolf and Jahnke, in which only recall of an item was required, whereas in recognition, the identification of a repetition was required. It does seem reasonably clear that as the nature of the experimental task can produce results in the opposite direction, there is no need to postulate a dichotomy in underlying mechanisms.

In another experiment Jahnke and Erlick (1968) whilst noting similarities in the serial position curve for recognition and recall, also note that the curve is unchanged by increasing delay, unlike recall.

≠ 1. Footnote: As will be seen in Chapter 6, it is likely that opportunities for organisation, rather than repetition as such, facilitate retention.

≠ 2. Footnote: The experiments of Lachman et al (1966) is in itself an oddity in that after 128 repetitions, recall was better than recognition, although the authors account for this in terms of serial order eventually helping recall.

Whilst one must allow that these findings, which were obtained for serial material within the memory span i.e. 7 digit sequences, are difficult to account for in terms of one system for recognition and recall, it is not obvious how they can be accounted for in dichotomous terms.

There are indeed other findings which are awkward to account for, the experiment of Lachman et al (1968) discussed earlier, being one. Another is the finding of Shepard (1967) and Gorman (1961) that frequent nouns are less well remembered than non frequent nouns (using recognition) contrary to the findings from recall experiments of Lloyd (1964). Again Young et al (1968) found a cross-over effect, with recognition superior for high frequency words immediately after presentation but inferior for low frequency words 24 hours later. The experiment of Turnage (1967) is of relevance here. Using a recall task he found high frequency words better recalled immediately, but that after 30 secs. low frequency words were better retained. This fits in, at least to some extent, with the findings of Young et al (1968) on recognition. It may well be that these contrary findings are a function of the experimental designs used, particularly in relation to the time interval between presentation and retention test. This is a ressonable assumption to the extent that different experimental designs were employed in all the experiments. Thus, unlike other experiments, that of Lloyd involved a sequential memory task, in which recall then was required more rapidly than for normal memory tasks.

Despite the problems posed for a single system for recognition and recall, at best by one or two isolated experiments, it seems clear that the vast bulk of experimental evidence indicates a large measure of communality in the organisational properties of recognition and recall, and makes the hypothesis that recogntion involves storage of uncoded images untenable.

It must be admitted that Adams is not entirely clear as to what he regards as the nature of the S-perceptual trace. Whilst on P. 269 he does describe the trace as an uncoded image, he earlier quotes, without comment as to whether he accepts what he quotes, from a paper by Sheffield (1961). Sheffield refers to sensory responses, which are certainly not uncoded images as they are assumed to be subject to learning principles of association by contiguity. Further Sheffield notes that they <u>need</u> not (as opposed to <u>do</u> not, which Adams claims) have any motor component.

It may be, therefore, that Adams holds that recognition and recall have the same organisational properties, and are subject to the same kind of forgetting factors, but differ only in that items recalled have a response potential, whereas items recognised do not, and indeed never have had such a potential. If this is what is being claimed, then the situation is somewhat more complex. It is not obvious to the writer that it is empirically possible to distinguish such a theory from one which regards the relationship between recognition and recall, as one within a single memory system, in which partial learning or forgetting accounts for the inability to recall, but only recognize an item.

Take for example the evidence which Adams himself puts forward, that one can achieve high recognition rates for stimuli which are difficult to verbalise i.e. nonsense shapes, e.g. Deese (1956) Clark (1965), and are thus based on a pure 'S' perceptual trace. It seems reasonable to suppose that such figures contain little redundancy and are, therefore, difficult to process, taking a long time to be fully learned. Yet such shapes are likely to be relatively unique so that partial learning will be enough for identification.

There has, in fact, been a recent attempt to consider whether recognition and recall differences could be attributed to two differential storage processes, or whether retrieval differences were involved. The study, by Freund et al (1969) involved examining differences between recognition and recall when subjects were unaware at the time of presentation by which mode they would be tested. As they found no differences for recognition and recall as a function of this variable, they concluded that this was consistent with retrieval differentiating recognition and recall. Yet this experiment, as the authors themselves admit, is merely consistent with this supposition, it does not disprove the possibility that all items automatically enter a recognition memory and may also automatically enter a separate recall memory.

If it is empirically impossible to distinguish the dichotomous and non-dichotomous recognition/recall theories outlined above, it is reasonable to assume, on the grounds of parsimony both at a biological and explanatory level, that recognition and recall are related within the same memory storage system. Thus it appears biologically unparsimonious to have a duplication of memory systems, in which both have the same organisational properties. It is unparsimonious at an explanatory level in that the organisational principles of memory established by using recall tasks appear more or less to fit the organisational principles found by using recognition tasks.

If then, one assumes that recognition and recall are not dichotomous memory storage systems, various possibilities concerning the relationship between the two can still be hypothesised.

Dichotomous Retrieval Systems

The second dichotomy which has been suggested, e.g. by Kintsch (1968), is in terms of retrieval systems, indeed with other writers, e.g. Schonfield and Robertson (1966) and Murdock (1968), he suggests that only recall involves retrieval. Schonfield and Robertson quote Deese (1963) "In recall a subject must produce a set of responses, whereas in recognition the set of responses is produced for him". One might well agree, to a large extent at least, with Deese, and yet argue that the terminology of writers such as Schonfield and Robertson is unhappy. If retrieval is defined in terms of whether the subject must produce his own cues (or most of them) whereas, in recognition this is unnecessary, then the view of Schonfield and Robertson may just be tenable. The experimental evidence of Cofer et al (1969) and Light and Carter-Sobell (1970) however, indicates that as changed semantic context between input and output can inhibit recognition, some search process is needed to account for this; recognition cannot merely be in terms of identifying a recently given item. In other words in recognition, retrieval cues, in the form of context are given, just as is the case with recall. Available information, to quote Tulving and Madigan (1970) is not "automatically accessible" when an 'old' item is presented. Again, such writers as Tulving (1968) look on retrieval as trace utilisation, and in this sense the distinction between recognition and recall is not in terms of the requirement of retrieval from storage, as clearly the stored material is utilised even in recognition, in that at the very least some matching of new and old information must take place.

Retrieval, in fact, as Freund et al (1969) note, is too broad a term to be functional in this type of analysis, and the distinction made between various aspects of retrieval by Shiffrin and Atkinson (1969) has therefore some appeal. They distinguish search, recovery and response generation. Search involves the location of stored information.

Recovery is the process by which the information is made available for response, and finally response generation is the process which compreses all aspects of translating the recovered information into the desired response, which might include the utilisation of partial information in order to guess responses.

Norman (1968) regards recognition and recall as differing in terms of differences in the question asked of the storage system and hence differences in the search process. P 533 "In recall the task is to regenerate an item given its context - ("what word were you shown yesterday?"). In recognition the required task is just the reverse. Here the item itself is given; the question is whether the context surrounding the item is appropriate ("Is this the word you were shown yesterday?"). Note that the recognition task does not require the same type of search used in recall, the recursive query - output - decision - query chain is not needed. All that is required in recognition is an assessment of the appropriateness of the various associations surrounding a stored item to the association demanded by the query".

If Norman regards the information that the words "you were shown yesterday" indicate the giving of context in the case of the recall task, it is difficult to see why this should not also be giving the context for a recognition task. In the recall task as well as the recognition task one must presumably check the appropriateness of any item located in store in terms of its appropriateness, i.e. in terms of the various associates surrounding the stored item. It may be that more than one match mismatch operation is not required in a recognition as opposed to a recall task, but this hardly necessitates the postulation of two types of retrieval process (search).

It seems reasonable therefore, to go along with Shiffrin and Atkinson (1969) when they conclude on the question of recognition and recall P171. "Hypothesès which ascribe different retrieval mechanisms for recognition and recall are not necessary.In both recognition and recall the presented stimulus will be sorted into an L.T.S. area and a search initiated there. In the case of recognition, the search can be quite limited, perhaps consisting of an examination of a single image." Gruneberg (1969b) was getting at the same point P.322.,when restating Hunter's(1964) suggestion that as one moves from giving few retrieval cues to giving many, one is going from a recall to a recognition task.

A According to this type of analysis, one might argue that what Schonfield and Robertson are saying is that in single item recognition all the cues to the location of information are given, the subject merely has to indicate whether the information is stored where the cue indicates, whereas in recall such cues are not given and the subject has to search a larger area of storage on the basis of what cues he has. Of course in recognition tasks the full information may not be stored or the strength of the trace may be weak, relative to other similar traces .In such a case a decision has to be made as to whether an item is old or new. This decision is affected by response generation, which may well involve response bias.

A further distinction that is claimed between recognition and recall concerns the effects of list organisation on retention. Kintsch(1968) found that the organisation of a list aids recall but not recognition. This he considered evidence for a dichotomy of retrieval systems. On the other hand Bower et al (1970) Lachman and Tuttle (1965) Rosenberg (1968) and Mandler et al (1969) did find recognition aided by list organisation. Whilst there is no obvious explanation of these discrepant findings, it does not seem necessary in our present state of knowledge, to dichotomise between recognition and recall on the grounds which Kintsch suggests.

If one allows, then, that recognition and recall do not differ in terms of differing storage retrieval systems, but that recognition involves less of a search than does recall (perhaps one match mismatch as opposed to many) then the two major problems posed at the beginning of the chapter are answered. First, recognition experiments do have implications for findings based on recall experiments, and second, it seems unnecessary to consider whether there are four rather than two memory systems over time. Nevertheless, two further problems remain.

In the first place one is faced with the question of whether the amount of information which can be obtained by recognition and recall is merely a function of the task set, or whether there are real differences in the amount of information which can be obtained by using the two methods. The second problem follows on from the first. If recognition tests yield additional information about the amount of information in store compared to tests of recall alone, how does this come about? Is it, for instance, because in addition to information which can be obtained by recall as a result of complete information storage, other information of a less complete nature is stored, which can only be located by the use of efficient search cues, or might there be other explanations? These two problems are now considered in turn.

Information revealed by recognition and recall

Bahrick (1964) has proposed that differences between recognition and recall are in terms of differences in the nature of the task and do not reflect underlying differences in memory. He claims that the higher recognition scores may reflect a higher degree of original learning, in that it requires fewer trials for recognition to reach a given criterion than recall. If one gives the same amount of learning opportunity to a recognition and a recall task, then the former will receive a higher degree of original learning. If one could reduce the learning opportunities for recognition until they were equal to that of recall, differences would presumably disappear.

As Field and Lachman (1966) however, point out, the issue of whether recognition is superior to recall is by itself meaningless. The appropriate question is that concerning the conditions which lead to superior recognition performance contrasted with recall performance. Thus Gruneberg, Experiment 2 Chapter 7, (1969 b) also has shown that following a single presentation of a list of words, recognition measurement indicated many more items in store than a previous free recall task had indicated. Using different experimental designs, and different materials, Brown (1965), Postman et al (1948), Kay and Skemp (1956) and Brown and Packham (1967) have all shown that recognition is superior to recall, after recall has run its course - this despite interpolated recall having a detrimental effect on later recognition in some instances (Postman et al, Brown and Packham). Bahrick (1964) may well be right, that this extra recognition was possible because it requires less learning than does recall, but it does not mean that recognition is not superior to recall given the same learning task. Recognition <u>is</u> superior to recall in the sense of indicating more items are stored as indicated by recognition than are indicated by recall, after all information obtainable by recall has been obtained. Again, of course, to argue that recognition is superior to recall only because less learning is involved is circular; the evidence upon which such an assertion is based is the larger recognition scores obtained by recognition tests after an equal number of trials.

Further attempts to account for recognition recall differences in terms of task differences have been made by Davies et al (1961) and Slamecka (1967). As has already been noted, these writers showed that increasing the number of alternatives reduced to zero differences between recognition and recall scores.

Again the evidence of Davies et al (1961) Teghtsoonian (1965) and Slamecka, cannot be taken as showing that recognition and recall do not normally yield differences in measured retention in favour of recognition. Rather the results indicate that the relationship between recognition and recall is of a non dichotomous nature. Thus recall may be inferior to recognition for the reason that Slamecka suggests, indicating that perhaps the larger number of alternatives to be considered in recall increases interference relative to the recognition processes, as has previously been suggested. It is still important to stress that whilst one can devise tasks in which recognition is not superior to recall, by reducing recognition scores, one still has evidence, e.g. Shepard (1967) Gruneberg (1969 b) that the amount of information which can be shown through recognition is superior to that shown through recall. One must beware of arguing, by analogy, that because a man with his legs tied to a post cannot run any faster than a man with no legs there is no real difference between the running ability of a man with legs and a man without. Because one can reduce recognition scores to the level of recall scores does not mean that one can increase recall scores to the level of normal recognition scores. In the nature of things recall may involve more interference than recognition under normal circumstances.

It seems reasonable to assume that recognition and recall may be part of the same memory system, that recognition tasks may, under normal circumstances yield higher scores than recall tasks, and that this is not merely an artifact of measurement technique or task, in that recall scores have never been known to reach the level of recognition scores under normal circumstances. If, then, recognition tests yield greater evidence of storage of items than do recall tests, the next question is, why?

Partial Learning - acquisition or forgetting?

It has been suggested (Mc Nulty 1965, 1966) that the superiority of recognition over recall is due to recognition requiring only partial learning of information, whereas recall requires complete learning. Thus it might not be possible to recall that a word previously presented was Edinburgh but if one has learned the "Edin" part, then amongst a list of alternatives such as Edinburgh, Glasgow, London, correct identification would be possible. The critical question for present purposes is whether this partial learning is due to failure of acquisition or of retention i.e. forgetting of material previously acquired.

It does not seem unreasonable to suggest that both possibilities might be operating, depending on the experimental conditions. Thus at very fast rates of presentation it may be that only a part of the stimulus is acquired before the next stimulus is presented, and so on. In such a setting it might be reasonable to suppose that partial learning implies partial acquisition. Memory tasks, however, more commonly involve presentation rates such that categorisation of the stimulus is possible. Thus Rock (1957) notes that if one were to break into a sequence immediately after presentation, one would be able to obtain recall of the last item presented. There is experimental evidence that this is the case, e.g. Murdock (1963) and further evidence is presented by Gruneberg and Sykes (1969 b). In one experiment subjects were read a list of items at one per second and had to respond immediately (auditorally). This they succeeded in doing with only one or two errors out of 40 words presented. Again, as Schonfield (1967) notes it is not self evident why subjects should acquire part of a word, when it seems as easy to acquire the word itself.

It seems reasonable to suppose, therefore, that where categorisation of items has taken place, (at presentation rates of 1 item per second at least) then in looking at the relationship between recognition and recall one is dealing with the problem of forgetting. What therefore, is the cause of forgetting such that recognition only is possible where once recall was possible? Various possibilities present themselves.

Forgetting can, in fact, be accounted for under three general headings. (1) There may be degeneration of an underlying trace for neurological reasons which are independent of experience (autonomous trace decay); (2) There may be degeneration of the underlying trace through experiential factors, e.g. displacement or compression etc., or (3) there may be forgetting for reasons unconnected with the loss of the underlying trace, i.e. retrieval problems, e.g. competition of responses

These possibilities, in other words, are reflections of the possible mechanisms of forgetting, with which the next chapter will be concerned. Even if it is not possible to solve the problem of the nature of rapid forgetting, however, chapter 7 indicates the importance of the relationship between recognition and recall in an analysis of the limited capacity hypothesis, and the non dichotomous nature of the two is assumed in an experimental attack on semantic and acoustic interference effects in short and long term memory.

The foregoing analysis of the relationship between recognition and recall has also interesting implications for the more general question of the grounds upon which a dichotomous theory of memory can reasonably be held. Many psychologists who hold that short and long term memory are separate systems, nevertheless maintain that recognition and recall are not dichotomous. Norman and Wickelgren (1969) both dichotomists, deny a dichotomy to recognition and recall, on the grounds of similar reactivity of recognition tasks and recall tasks to such variables as repetition. This very reason was advanced by Melton (1963) to reject a dichotomy between short and long term memory. Furthermore the large difference in capacity between recognition and recall, has its parallel in the distinction between short and long term memory (Adams 1967).

If evidence of communal organisational characteristics is sufficient to reject a dichotomy between recognition and recall, despite operational differences, it is not obvious why this principle should not be extended to the distinction between short and long term memory.

Finally, it should be stressed that whilst of great importance to an analysis of differences between STM and LTM, any inadequacy of interpretation of the relationship between recognition and recall is not critical to such an analysis. In almost all cases, empirical evidence exists using both recognition and recall, which casts serious doubt on either being indicants of underlying dichotomous memory systems.

Summary

This chapter has concerned itself with an analysis of the relationship between recognition and recall. This analysis was noted to be necessary in the context of a thesis on differences between short and long term memory, both because of methodological implications, and the theoretical possibility that a dichotomy between recognition and recall might involve further distinctions between short and long term memory.

The first possibility considered was that recognition and recall differed in terms of the underlying storage mechanisms employed. The possibility that recognition consisted of uncoded images was examined and shown to be inconsistent with a large amount of evidence which indicates organisational characteristics of recognition memory. The possibility that recognition memory is a separate storage system with, however, the same organisational characteristics as recall memory seems to be empirically undistinguishable from a theory which claims that recognition and recall are part of the same storage system.

The next possibility considered was that recognition and recall differed in terms of underlying retrieval mechanisms, it even being suggested that the question of retrieval did not apply to recognition.

The analysis of the retrieval process by Shiffrin and Atkinson (1969), however, indicates that the term retrieval is too broad to be of functional value in this type of analysis, and a distinction between search, recovery and response generalisation is useful. Such an analysis reveals that differences between recognition and recall are likely to be in terms of the amount of search required, not in the utilisation of stored material. As Shiffrin and Atkinson (1969) note, it does not appear necessary to hold, therefore, that recognition and recall have different retrieval mechanisms. Thus it appears reasonable to view findings based on recognition experiments as relevant to findings based on recall tasks, and it appears unnecessary to consider the question of whether there are four memory systems over time, rather than two.

Two further problems were next considered. Can recognition scores reveal that more information is stored than can be obtained by recall scores, and if so, why? The empirical evidence is that after recall has been required, a recognition task can reveal evidence of further storage. It was then suggested that whilst partial learning can account for this superiority of recognition, it is likely to be partial learning as a result of failure of memory, rather than partial acquisition, in normal memory tasks.

The question of the relationship between recognition and recall is then seen as being intimately bound up with the cause of forgetting, particularly rapid forgetting and that the different possibilities implied by different mechanisms of forgetting, relating recognition to recall have profound effects on the interpretaion of empirical data will be seen in subsequent chapters.

CHAPTER 6

THE NATURE OF FORGETTING

In Chapter 4 it was noted that forgetting can in part be accounted for under three general headings. 1. There may be degeneration of an underlying trace for neurological reasons which are independent of experience (Autonomous trace decay). 2. There may be degeneration of the underlying trace through experiential factors, e.g. Displacement or compression etc. or 3. There may be forgetting for reasons unconnected with the loss of the underlying trace, i.e. retrieval problems.

The terms trace decay and interference are often used in the literature to account for the possible causes of forgetting, e.g. Hilgard and Bower (1966) Waugh and Norman (1965), and undoubtedly one of the major confusions in the field arises because the term interference is used by different writers to either include or exclude the second category above. Waugh and Norman (1965) for instance regard displacement as an aspect of interference, and Adams (1967) regards interference as any process which cannot be regarded as autonomous trace decay. Wickelgren (1969 b) who has frequently argued for an associative interference explanation of forgetting in short term memory (1965 a, 1965 b, 1969 a) appears to advocate that associative interference results in trace decay, as do Posner (1967), Posner and Konick (1966). Brown (1964) too, talks of experiential factors causing decay as "interference with the trace", but he does point out that "competition" from previous or subsequent learning is the basis of "interference theory".

Melton (1963, 1964, 1967 a) who with Irwin (1940) is responsible for the two factor interference theory, quite clearly regards interference as involving processes which exclude the possibility of storage loss, and he quite clearly regards the classical theory of interference proposed by McGeoch (1932) in the same light. Thus (1967) p. 54 "Interference theory, as applied to LTM has no permanent erasure component. It has merely competition of response at the time of retrieval." Shiffrin and Atkinson (1969) are thus in error in contrasting their permanent storage hypothesis for interference theory in LTM with that of a non permanent store for Melton's theory. Again Melton (1967) P 228. "Interference, in the classical theory of forgetting, is a theory which says that interference is at the time of attempted retrieval. Both habits are established. It is not interference in the sense of erasure of a trace or anything like that. The only additional hypothesis of the theory is that there is a temporary - and I emphasise temporary - unlearning of the first of the two habits, if such is required for the learning of the second." There can be no doubt that for Melton at least, interference does not include the possibility of trace decay as a result of experiential factors (experiential trace decay).

It is not the purpose of this chapter to review in detail the various theories of forgetting. Many other writers have done this, and such reviews as those of Postman (1961) Keppel (1968 a) Hilgard and Bower (1966) Jung (1968) and Adams (1967) can be consulted for a fuller exposition. What isof importance, as noted in Chapter 4, is a consideration of whether there is evidence that the cause of forgetting in the short term is not the cause of forgetting in the long term.ɸ In other words what will be undertaken is an analysis of the

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ɸ Initially a distinction will be made between autonomous trace decay and interference theories, in order to demonstrate that even a "pure" interference theory is difficult to distinguish, experimentally, from an autonomous trace decay theory. The position of experiential decay theories will be considered later in the chapter.

evidence which is claimed to differentiate autonomous trace decay theory from interference theory, particularly in relation to the time scale over which these are claimed to operate.

Various lines of evidence have been used to support one theory at the expense of the other; these are now listed.

1) Similarity: It is claimed by interference theorists that similarity effects indicate interference, e.g. Wickelgren (1965 a). However, autonomous trace decay thorists claim that lack of similarity effects in the short term indicate autonomous trace decay.

2) Rate of Presentation: It is claimed by autonomous trace decay theorists e.g. CONRAD AND HILLE ~~Brown~~ (1958) that rate of presentation affects rate of forgetting in such a way as to indicate autonomous trace decay. Interference theorists on the other hand, deny the unequivocal nature of the evidence, and point to other evidence which shows the number and nature of items interpolated between presentation and recall to be critical, rather than time per se.

3) Proactive Inhibition: It is claimed by interference theorists that material presented before presentation of a critical item affects retention, Murdock (1961), Turvey (1967).

4) Repetition effects: It is claimed by interference theorists that the orderly increase in retention with repetition indicates a single memory system, Melton (1963).

5) Reminiscence effects: Evidence of retrieval of material previously considered decayed is of embarrassment to a trace decay theory, McGeoch (1942)

6) Modality effects: The evidence cited by trace decay theorists is that in a Peterson and Peterson design, the first item in a sequence

visually presented is not forgotten after 18 seconds whereas, using auditory presentation, a certain amount of forgetting does take place, Peterson (1966 b).

7) <u>Intrusion errors</u>: The evidence from changes in the pattern of recall errors over time, where errors are shown to be similar to correct responses, initially (Conrad 1964).

Before going on to consider the evidence for and against these lines of evidence in short term memory, where almost all the evidence for trace decay comes from, it is useful to consider the question of similarity in long term memory.

<u>Long Term Forgetting</u>

There is, in fact, very little dispute that what is termed interference causes forgetting in long term memory amongst those holding either a single system or a dichotomous theory of memory e.g. Underwood (1957) Broadbent (1963), at least to the extent that it is allowed that experiential factors reduce the amount of material retrieved. Brown (1958), (1959), (1964) and possibly Conrad (1967) are exceptions, regarding long term memory as involving autonomous trace decay. Apart from the famous experiment of Jenkins and Dallenbach (1924) confirmed by Ekstrand (1965), in which it was found that when interpolated activity was minimal so was forgetting i.e. during sleep; many of the older experiments e.g. McGeoch and McDonald (1931), Underwood and Goad (1951) found experiential factors to affect forgetting over the longer term. McGeoch and McDonald found that for learned materials, synonyms as interpolated activity resulted in higher forgetting i.e. greater RI, than was the case with material unrelated to the learned material, and McKinney (1935) showed the phenomenon of RI using a recognition task. Whilst many of the earlier studies attributed interference to retroaction, Underwood (1957) noted that many of the earlier studies were open to the criticism that they used the same subjects repeatedly, leaving open the possibility that proaction was responsible for a large amount of forgetting, and he succeeded in demonstrating that his was in fact the case, a finding later confirmed by, amongst others, Seidel (1959).

Whilst Hilgard and Bower (1966) and Brown (1964) note that interference theory is the most popular theory of forgetting, whilst Neisser (1967 and Peterson (1966 b) regard it as essential to account for at least some forgetting in terms of interference, and whilst Adams (1967) regards interference as the only empirically defensible theory of forgetting, it does, as for instance, Jung (1968) and Tulving and Madigan (1970) point out, have some serious problems, the major one of these being the lack of support for an extra experimental interference hypothesis. This hypothesis assumes that the learning of a verbal list in the laboratory interferes with previously learned verbal responses and partly extinguishes them; these partly extinguished responses then recover and the conflict between these responses and the newly learned responses is claimed to lead to forgetting. This hypothesis is necessary in order to account for forgetting in subjects naive as far as verbal learning tasks are concerned. For non naive subjects, previous learning tasks serve as a potential source of interference, of course.

The hypothesis assumes that the more frequent a word, or more meaningful, the more associations it has to recover and interfere with the learned items. Thus the most meaningful associations show less retention. This hypothesis and similar ones derived from the original hypothesis were not confirmed in a number of studies, e.g. Underwood and Postman (1960) and Postman (1962). Various suggestions have been made as to why extra-experimental interference has not been demonstrated. One plausible explanation, suggested by Keppel (1968 b) is that subjects can isolate the habits learned inside and outside the laboratory, to some extent - the "selector mechanism" is too efficient. Again Keppel (1968 a) has suggested elsewhere that RI might be responsible for such forgetting as does occur, and Jung (1968) also advocates this explanation.

Despite the problems posed for an interference theory by the failure to support the extra-experimental interference hypothesis, abundant evidence exists for the association of experiential factors with forgetting over the long term.

The basic problem in differentiating the three general theories of forgetting is that all of them can account for the effects of similarity and previous experience on forgetting, a fact which is overlooked by Adams (1967) and Neisser (1967) but which Keppel (1968 b) Hilgard and Bower (1966) and Norman (1969) note.

In fact, as far as long term memory is concerned, the evidence upon which interference theory is largely held, similarity effects, is not fatal evidence against an autonomous trace decay theory, in that it can account for the effects of similarity on forgetting. Thus Brown (1958) and Conrad (1967) have accounted for the effects of similarity on forgetting by noting that interference may be the result, not the cause of forgetting. In accounting for the increase in forgetting as a function of the number of preceding items in the experiment of Keppel and Underwood (1962), Conrad (1967) suggested that trace decay results in a progressive loss of characteristics which may differentiate one item from another. For example, after only one item has been presented, decay of that item will not result in appreciable forgetting because there is nothing to confuse that item with. After a second item is presented however, decay of aspects which differentiate one item from another becomes much more problematic from the point of view of having to retrieve the correct item. Thus if the item KAZ is given first, its decay to K$\bar{A}$Z (where $\bar{A}$ is a blurred letter) will still enable retrieval to take place. If a second item KOZ is now introduced, its decay to K$\bar{O}$Z will preclude the possibility of distinguishing the two items. In fact, both the effects of previous experience on later forgetting (PI) and the effects of similarity on forgetting, can be accounted for in such terms, and Brown (1959) is arguing for autonomous trace decay over both the short and the long term, with decay rapid at first, less rapid later on. That Brown and Conrad have argued for a trace decay theory using short term memory experiments, should not blind one to the fact that this type of explanation can be used to justify the holding of an autonomous trace decay theory for long term memory.

Short Term Memory

1) Similarity

It is in the study of forgetting over the short term that much of the evidence, noted at the beginning of the chapter, in support of one theory or another is obtained, and it is in the short term only that autonomous trace decay is claimed to operate, e.g. by Broadbent (1963). Broadbent claims that whilst similarity does affect long term forgetting, so that interference can be assumed to operate, the effects of similarity on forgetting cannot be demonstrated over the short term. For a long time this appeared to be true and Posner (1967) notes an early study in which similarity effects over the short term were not found. Again Brown (1958) SUBSTANTIALLY made this claim, and even very recently Glanzer et al (1969) have restated that similarity has no effect on forgetting in short term memory. The inference from this is that associative factors do not operate to produce forgetting, whatever the interference forgetting mechanism is claimed to be.

The empirical evidence, is however against such an assertion, and whilst it may be more difficult to show the effects of similarity over the short term than over the long term, these have been shown. Thus Wickelgren (1965 a, b) has shown that the amount of forgetting varies with the auditory or linguistic similarity between the series to be recalled and the interfering material. Using a recognition task, Underwood and Freund (1968) showed the effects of both acoustic and semantic similarity on recognition rates in the short term. Semantic similarity does, however, seem to have a weak effect over the short term, and this was the effect that Glanzer et al (1969) failed to find, a restatement of Broadbent's (1963) earlier assertion.

Wickelgren (1965 a) having shown the effects of interference in STM certainly argues for the possibility that STM and LTM are continuous, but Glanzer et al (1969) have questioned whether the experimental procedures used by Wickelgren indicate short, as opposed to long term memory effects. To argue in this way, however, entails the possibility that one can have rapid forgetting from long term memory, in that Wickelgren showed acoustic interference effects within 30 seconds, and as noted in Chapter 4, such an admission collapses the basis for holding a dichotomous theory of memory. Furthermore, even on Glanzer et al's (1969) "criterion" of output from STM, the "recency" part of the serial position curve, the effects of similarity on forgetting have been shown. Craik (1968) and Kintsch and Buschke (1969) have shown the effects of acoustic similarity on the recency part of the serial position curve.

Perhaps the most influential experiment in extending interference theory to short term memory has been that of Keppel and Underwood (1962) who questioned whether rapid forgetting of three letter trigrams indicated autonomous trace decay, as had been suggested on the basis of the experiments of Peterson and Peterson (1959). Keppel and Underwood showed in one experiment, that there was relatively little forgetting in the first trigram presented, but that retention became progressively worse as more trigrams were presented, resulting in the rapid forgetting that Peterson and Peterson had observed. This was a reasonably clear demonstration of the effects of PI in the Peterson and Peterson type of experiment, and this helped to extend the theory of interference to short term memory. It seems reasonable on the basis of Keppel and Underwood, and of Wickelgren and others, to conclude that similarity is associated with forgetting both in proactive and retroactive designs, in the short term.

These results, then, are supportive of an interference theory of forgetting, but as was noted in discussing long term memory, they are by no means fatal for an autonomous trace decay theory, which now poses the question as to whether such similarity effects, assuming they exist, are the cause or the result of trace decay. In other words a trace decay theorist can still argue that trace decay causes similar items to be confused and to interfere with one another.

2) Rate of Presentation and Interpolation of Items

Evidence claimed to support a trace decay is the evidence of Conrad and Hille (1958) that rate of presentation of items per se has an effect on retention, the slower the rate of presentation the greater is forgetting, which of course is the result of autonomous trace decay. As Posner (1964) and Aaranson (1966) note, however, the evidence is not unequivocal, and Mackworth (1962) and Pollack et al (1959) report findings in the opposite direction, although Posner himself confirms the evidence of Conrad and Hille. Posner suggests that the contradiction in findings can be resolved if one takes account of restraints in recall, and Neisser (1967) also suggests that this might be important. Yet as Aaranson (1966) points out, the experiment of Mackworth (1962) involved both ordered and unordered recall, and Posner's (1964) experiment involved reversed recall, in which it was found that at slower rates the earlier items were better recalled. How is it, Aaranson asks, that the longer an item is in store, the better it is recalled, if autonomous trace decay is operating? If anything, in fact, the evidence in this field is supportive of interference theory.

Waugh and Norman (1965) for instance, using a probe technique, found that reponse did not depend on time but the number of interpolated items. Their experimental method consisted of presenting items at a rate of one per second and at a rate of 4 per second, then requiring recall of an item in the sequence by asking for recall of an item subsequent to an item which was given by the experimenters at the end of the sequence. Glanzer et al (1969) also found that it was the number of interpolated items, not the time between presentation and retention test, which caused forgetting, again not supporting an autonomous trace decay position. The evidence in this area is clearly not unambiguous. Yet, as with other evidence, it is not clear that the evidence is fatal for an autonomous trade decay theory. Thus Hilgard and Bower (1966) point out that where one finds no difference in the amount forgotten for different rates of presentation, this could be because slower rates of presentation allow for more opportunities for rehearsal. This greater rehearsal (or indeed any other process going on in time) could be offsetting the larger time interval.

Just as with interference theories, there are areas in which autonomous trace decay theory is uncomfortable. For instance, Neisser notes that autonomous trace decay is likely to be too slow to account for findings that very rapidly presented sequences of digits are difficult to recall. Even allowing partial decay of these sequences does not account for their being more difficult to recall than more slowly presented similar sequences. Perhaps some form of processing at slower rates of presentation counteracts this decay for slower rates of presentation, as Hilgard and Bower suggested in accounting for Waugh and Norman's (1965) experiment.

3) Proactive Inhibition

Two experiments, one by Murdock (1961) and one by Turvey (1967) are also problematic for an autonomous trace decay theory. In the first it was found that irrelevant words before a critical "to be remembered" item reduced retention of the critical item after an interpolated activity. Turvey showed that where items were homogenous and unrelated to a later critical item, retention of the critical item was higher than when the prior words were heterogenous. The problem raised by both these experiments is how items unrelated to later items can affect later retention, and in particular why unrelated items which are homogenous with respect to each other, but different from a critical item, can affect retention to a greater extent than items which are heterogenous.

One possibility in the case of Murdock's experiment is that whilst "Proactive" words were unrelated to the critical item as far as the experimenter was concerned, they were similar to the critical item along various dimensions,ie. all were English words, given within a short time of each other, thus sharing a similar "time tag". Hence decay might lead to some confusion. As far as the Turvey experiment is concerned, one might use the same argument for the heterogenous items; their very heterogeneity made the critical item part of the heterogenous list. Because of the homogeneity of non-critical items in the other condition, the critical item was different enough on the dimension which was common to the other items to be distinguished more readily from the other items, despite partial decay.

4) Repetition effects

The evidence cited by Melton (1963) as supporting an interference theory, the orderly increase in retention as a function of repetition, has recently been questioned. Hilgard andBower point out that whilst repetition effects are claimed to support interference theory, in that they are interpreted in terms of strengthening existing associations, they can be handled by autonomous trace decay theory in that various possibilities can be suggested.

a) Repetition may establish multiple traces;

b) Repetition may change the rate of decay of a single copy;

c) Increase the probability that items are transferred to long term memory;

d) Delay the onset of normal dedays processes.

The problem is that recent evidence on repetition effects suggests that repetition as such may have none of these effects; thus repetition may reduce the amount of material retained, or at least retrievable, compared to an unfilled interval. Glanzer and Meinzer (1967) using a free recall technique found that repetition reduced the level of the asymptote, interpreted by dichotomous theorists in terms of long term memory. Eagle (1967) also found that those who rehearsed by repetition were inferior to those who rehearsed by association, using a free recall experiment and Dalrymple - Alford (1967) failed to find any improvement in retention as a result of mere repetition.

Further evidence that repetition per se does not appear critical comes from Melton (1967 b) who found that recall increased as the interval between the occurrence of two items increased, and Sitterley (1968) found recall performance to decrease whenever either digit duration or interdigit interval decreased, and concludes that old information is being processed as new information is coming in. If this is the case, then repetition per se would appear not to be the important factor in increasing retention, but rather processes which allow for organisation of material - Bartlett's "Effort after meaning".

Whilst therefore, none of the interpretations of repetition effects in terms of trace decay suggested by Hilgard and Bower seem adequate to account for the data on repetition, because they are founded on a false premise, the same argument can be made against interference theory. It seems best to assume at present that repetition is normally involved when there is "Effort after meaning" or some attempt at organisation and it is this which improves retention. Perhaps the effect of this organisational factor is to reduce the amount of trace decay or interference. In other words, the many studies which do show repetition to improve retention e.g. Waugh (1962), Lachman et al (1966) may do so by providing opportunities for reorganisation. At least it seems clear that for example Posner (1967) is in error inequating rehearsal with massed repetition.

The evidence that a single exposure is enough to establish a permanent trace (Hebb 1961, Melton 1963) compliments evidence on repetition effects. If a single presentation of material produces a permanent structural memory change, this is at variance with the hypothesis that material in short term memory is lost through autonomous decay, unless rehearsed. The experimental evidence that Hebb and Melton produced was that a single presentation of a digit sequence results in evidence of retention even after the interpolation of large numbers of different digit sequences. Cohen and Johansson (1967) found that where overt rehearsal was prevented, no improvement in retention occurred. Cohen and Johansson's evidence does not disprove the possibility of permanent storage, it does appear to make the evidence of Hebb and Melton inconclusive.

5) Reminiscence effects: The retrieval of previously irretrievable items

As Osgood (1953) for example, points out, the problem of reminiscence is one which a trace decay theory has difficulty in coping with. If a trace has decayed or been lost from the memory system, how can it be retrieved at a later stage than that of its assumed loss. Brown (1959) answered this by assuming new retrieval techniques might uncover material not previously amenable to retrieval, and the evidence of Tulving (1962) certainly supports the view that retrieval cues improve recall. Provided therefore, the trace has not completely decayed, reminiscence effects can be accounted for by trace decay theory. A classical interference theory, too, has little trouble in accounting for reminiscence effects in terms of the spontaneous recovery of previously extinguished responses. Spontaneous recovery may be due to dissipation of fatigue effects perhaps.

Peterson (1966 c) conducted an experiment in which the last items of a series were better recalled after a short period, than was possible immediately. He interprets this evidence as showing a dichotomy of systems, in which improved retrieval indicates switching from one system to a more efficient system of retrieval. The interpretation is almost identical to Brown's except a dichotomy is claimed. Yet the evidence that the use of more efficient retrieval systems can aid immediate retrieval, noted above, makes it extremely dubious that an underlying dichotomy exists. In any case, an alternative explanation in terms of interference theory, noted above, prevents the establishing of a dichotomous theory on this type of evidence. Again, as has been noted previously, a classical interference theory does not entail a dichotomous theory of memory.

6) Modality effects

Paradoxically perhaps, the experiments of Keppel and Underwood have been used as evidence for autonomous trace decay by Peterson (1966 b)

Peterson notes that with visual presentation there was virtually no forgetting of the first trigram presented, after interpolation of activity lasting 18 seconds. With auditory presentation, however, there was some forgetting even of the first item presented. As Pro-active interference can hardly be taken to account for this forgetting, and as Retroactive interference was identical in both cases, it is argued that the auditory forgetting must be due to autonomous trace decay. Peterson does not argue against interference causing forgetting in the short term, but argues that autonomous trace decay also occurs, only it is not always observed.

Whilst this is an ingenious argument for autonomous trace decay, the findings can be accounted for by arguing for differential retro-active interference in the two experiments. Thus the interpolated activity involved in an auditory task, counting backwards aloud, might well result in producing sounds acoustically similar to those of the presentation trigram. A further objection is that many recent studies e.g. Murdock (1967) indicate that auditory presentation resultsi in higher storage than does visual presentation in the short term. As Tulving and Madigan (1970) suggest, auditory and visual information may be processed quite differently. Yet in view of the contradictory results, it is not possible to say at this stage that autonomous trace decay is operating in either modality.

7) Intrusion Errors:

One line of evidence which has recently been put forward as evidence of autonomous trace decay theory concerns the nature of intrusion errors in certain types of memory experiment. Thus, Conrad found that intrusion errors in sequences of letters were letters which sounded like the correct letter, e.g. P for V, and so on. Conrad argues that in a trace decay theory one would expect to find a degredation of the trace in which errors would start off being similar to the original item and gradually become more and more random.

As Keppel (1968 b) points out, however, there is good reason to suppose that such evidence is not critical in deciding between the two theories. This is because there is no reason why interference theory should not predict the same effects, in that it is not necessary to postulate an increase in interitem intrusion errors for interference theory. Thus it is not necessary to postulate a functional role for intrusion errors. The items which cause interference may not be selected in place of the forgotten item, because of the operation of other factors such as guessing. As Keppel notes there is ample evidence in the literature of LTM that the occurrence of errors is not correlated with assumed interference processes.

The evidence reviewed then, indicates that neither autonomous trace decay nor interference has been proved or disproved in either short or long term memory. In examining these two theories, however, no distinction was made between "Classical" interference theory, in which forgetting is due to factors other than storage loss, and interference resulting in trace decay, the "Acid bath" position of Posner and Konick (1966). Such a distinction, however, appeared unnecessary in the course of the analysis. This is because it is difficult to see what evidence would distinguish an autonomous trace decay theory from an "Interference causing decay" theory, if no evidence can be produced which can distinguish an autonomous trace decay theory from a classical interference theory. The question of which came first decay or interference, seems as insoluble as the hen-egg problem.

There are however, other experiantial trace decay or trace loss theories which do not depend on evidence of associative interference in the short term. Such theorists as Atkinson and Shiffrin (1968) and Glanzer et al (1969) rely on a displacement or overwriting model for forgetting in short term, in which experiential factors work through incoming items displacing already present items in a short term store. As noted previously however, the evidence produced by Waugh and Norman (1965) and Glanzer et al (1969) on the importance of the number of items interpolated, rather than time per se, as a cause of forgetting, does not rule out the possibility of a trace decay interpretation of the data.

It is not clear that the compression theory suggested by Murdock (1968 b) differs in essence from a displacement theory. Murdock's hypothesis is that after the limit of short term memory is reached there is a loss of some information from each item, rather than of all information from some items, which a displacement theory is presumed to require. Yet a compression hypothesis would appear to differ only in the detailof what is pushed out of store, and does not therefore seem essentially different from a displacement theory.

Again the empirical evidence against a pure displacement theory has been noted, the evidence of the importance of associative factors in forgetting. Finally, if one holds a displacement theory in spite of the evidence of similarity factors affecting forgetting in the short term, it is difficult to see why it <u>must</u> be abandoned as a theory of forgetting in the long term.

This chapter then, has not been concerned in detail with the evidence for various theories of forgetting, it has been concerned to illustrate that the issue of different mechanisms of forgetting over time has by no means been settled. This is by no means a revolutionary position to take as the following quotations will show.

Melton (1964) P 190. "We are not yet in a position to treat all long term forgetting as the product of interference factors alone."

Keppel (1968) P 192 "But for the comparison with STM, the question of critical importance is whether decay and interference interpretations can produce a set of clearly differential predictions. Several points of contrast may be suggested." (My underlinings). There can be little doubt that Keppel, whose name is very much associated with interference theory (e.g. Keppel and Underwood 1962) is not convinced that as yet, at any rate, the issue is settled beyond doubt. (Norman (1969) also basically an interference theorist, also has similar doubts).

Hilgard and Bower (1966) P 511. "as is the case with many such scientific debates, there is no completely clear resolution to this one, conceivably the issue is beyond resolving and may be destined to become one of those hardy perennials that continue to send up new sprouts every so often in the field of learning theory."

Brown (1958) P 20. "The results of the individual experiments have already been discussed. They fit well with the hypothesis of rapid decay of the memory trace when it is first established. It is not claimed that they are incompatible with alternative theories of forgetting." Peterson (1966 b) also an autonomous decay theorist, is willing to allow interference theory explanations in addition to trace decay. Thus both trace decay and interference theorists allow the possibility of the other theory being applicable.

Finally even Neisser (1967) who maintains that some form of interference theory is necessary admits P 239 "At least forgetting cannot be exclusively due to decay".

This writer, too, refuses to take a <u>definite</u> position on the question of the nature of rapid forgetting, being quite content to conclude with the authros just quoted, that all possibilities are open. Yet if all possibilities are open, so that either trace decay of interference might be operating in both short and long term memory, then a dichotomous theory of memory is also unproved, and if, as Hilgard and Bower suggest, the problem is beyond resolving, then so too is the question of a dichotomy between short and long term memory.

This in fact, is what the writer was implying when talking of a dichotomy being unprovable (1970). If one accepts, as Adams (1967) does, that interference is the cause of forgetting in short and long term memory, then a dichotomy becomes unprovable because it is impossible to distinguish two memory systems, and differing susceptibility of materials to those factors which universally cause forgetting. If trace decay is the cause of forgetting in short and long term memory then the same arguments hold, as indeed they do with any theory of forgetting which cannot be shown to be the exclusive province of either short or long term memory.

Rapid forgetting, it will be remembered, is the criterion by which it is decided material has not progressed beyond short term memory. The previous paragraph can be put in other terms. A failure to show that rapid forgetting has a different cause from less rapid forgetting entails a collapse of the criterion by which short and long term memory can be dichotomised. If rapid and less rapid forgetting can have the same cause, then it is possible for material to enter long term memory directly and be rapidly forgotten in that system. At the very least the evidence that different forgetting mechanisms govern short and long term forgetting is equivocal. As was noted in Chapter 4, the collapse of a criterion for distinguishing short and long term memory (through a failure to distinguish the mechanism of rapid and less rapid forgetting) entails the collapse of a dichotomous theory of memory on the grounds of parsimony.

Summary.

This chapter looked at the evidence for claiming that the cause of forgetting in the short term (rapid forgetting) differed from that in the long term. It was concluded that all the theories of forgetting could account for the phenomena of PI and RI, and other evidence which had been claimed to favour one theory rather than another, and that it could not reasonably be concluded that any one theory had been proved in either the short or the long term, to the exclusion of others. This being the case, the criterion for distinguishing short and long term memory collapses, as rapid forgetting cannot be taken to be indicative of the workings of the mechanisms of short as opposed to long term memory. In such a situation, a single system theory of memory must be held on the grounds of parsimony.

CHAPTER 7

THE LIMITED CAPACITY HYPOTHESIS/

STM Limited v. LTM unlimited capacity.

This present chapter and the following one are concerned with the limited capacity of subjects to recall recently presented information, in contrast to the normal subjects' capacity to recall large amounts of learned information. In this chapter it will be shown that in our present state of knowledge it is impossible to establish a dichotomous theory on the basis of this type of evidence. The following chapter will consider whether the experimental data presented by the writer on the question of limited capacity can even be adequately handled by a dichotomous theory of memory, were one to be tenable on other grounds.

That a distinction can be drawn between STM and LTM on the basis of the limited capacity of the former compared with the unlimited capacity of the latter has frequently been claimed. Adams (1967) puts this distinction forward as one of the three lines of evidence upon which a dichotomous theory can be based, pointing to the limitations of the memory span as evidence of our limited capacity in short term memory, and pointing to our virtually unlimited store of

/Footnote: Material in this chapter and the next has, in part, been reported in a paper by Gruneberg (1969 b)

Learned material and potential for learning material. Waugh and Norman (1965) also consider STM to have a limited capacity as do Hunter (1964) Atkinson and Shiffrin (1968) Miller (1957) and Glanzer (1968). It should perhaps be noted in passing that Glanzer and Cunitz (1966) attempted to dichotomise between STM and LTM on the grounds of the unlimited storage capacity of STM compared with the limited storage capacity of LTM. "By definition the short term mechanism is limited, not with respect to capacity, but to the amount of time it can hold an item". Glanzer (1968) has since changed his position to one where STM is limited to 3 - 6 items storage capacity.

Some writers are not entirely explicit as to what is limited, be it capacity to process, store or retrieve, whilst at the same time there is a great disparity of opinion amongst dichotomous theorists as to what is limited. Amongst those postulating limited storage are Atkinson and Shiffrin (1968) Welford (1968) McGhee et al (1965) Ingles and Ankus (1965) Glanzer (1968) Waugh and Norman (1965) to name but a few at random. Others, such as Baddeley et al (1969), Murdock (1965) and Crowder (1968) consider that the limitation might be in terms of processing.

Whilst it might be possible to interpret evidence of limited capacity to take in new information, in terms of storage, of processing or of retrieval, it is clear that any attempt to establish a dichotomous theory of memory on the basis of limited capacity must do so by showing that storage capacity in STM is limited when compared to the storage capacity of long term memory. That capacity to process incoming information perse, does not entail a dichotomy can be appreciated if one considers that the limitation on processing might be due to factors that cause forgetting in long term memory e.g. interference. In other words, it might be that the reason why processing capacity is limited, is that items are rapidly forgotten because of a rapid build-up of pro-active, or inter item interference, i.e. those factors which have been shown to affect retention over fairly long periods (Underwood 1957). Melton (1963) and Postman (1964) in fact use this type of explanation when accounting for rapid forgetting and limited capacity, in order to attack a dichotomous theory. Alternatively it might be that capacity to process is limited because items rapidly decay, and Brown (1958, 1959) opposes a limited storage capacity hypothesis with a trace decay theory of memory which does not imply a dichotomous theory. Of course it might be that there are two memory systems, and the limitation in processing is in terms of processing from one memory system to the other, as Baddeley et al (1969) suggest. The point being made is that in order to show this, it is necessary to show more than that there is a limitation in processing; it would be necessary to show that there are two memory systems on grounds other than limited processing capacity in order to establish a dichotomous theory of memory on grounds of limited capacity. (The grounds that Baddeley et al use - the serial position curve's differential reactivity to time - will be shown to be untenable as a basis for holding a dichotomous theory of memory in Chapter 10). In this chapter it is not claimed that it is impossible to interpret evidence of limited capacity over the short term in terms of a dichotomous theory of memory, only that it is not possible to establish a dichotomous theory on the basis of limited capacity.

The limited capacity of Retrieval in STM

Tulving (1968) has tried to hold a dichotomous theory of memory on the basis of dichotomous retrieval systems. That a dichotomous theory of memory retrieval systems cannot be established on the basis of the limited retrieval capacity of STM relative to the unlimited retrieval capacity of LTM needs no experimental support beyond the conventional forgetting curve. Let one suppose that a list of 60 words is presented to a subject; immediately after presentation he will be able to recall perhaps 10 of these. Unless after a period of time, all, or the great majority of the items become retrievable, then Long Term Memory has no unlimited retrieval capacity relative to STM for any given set of items. It is quite clear that retrieval over long periods of time is not unlimited relative to retrieval over short periods, as inspection of almost any forgetting curve indicates, despite the occasional reminiscence effect.

Tulving and Patterson (1968) do in fact suggest that STM has a limited retrieval capacity on the evidence of reminiscence effects. They do not consider the limited capacity of LTM on the basis of lack of retrieval of all items once in LTM. The experimental evidence cited by Tulving (1968) that following the presentation of 36 words, retrieval on three separate occasions showed only 50% of words in common, whilst showing the unreliability of memory span as indicating capacity, is of course irrelevant to the question of whether STM retrieval is limited relative to LTM.retrieval. Almost all the empirical evidence shows that at best, both in the short and the long term, there is a limited retrieval capacity for any given set of items. It should be noted that if all items we processed were permanently stored, and were LTM unlimited with respect to retrieval, one would be able to recall everything in one's past history at any given point in time that was not short term memory. It might be that a dichotomous theory can be established on the basis of dichotomous retrieval mechanisms using other evidence, but this dichotomy of retrieval systems cannot be established with respect to the evidence on limited capacity. Thus it may be that retrieval is limited in LTM for reasons different from those which limit retrieval in STM. To show this, however, it is necessary to establish criteria for distinguishing STM and LTM other than in terms of limited capacity. To show that STM is limited in terms of retrieval, is, in other words, insufficient to establish a dichotomous theory of memory.

"hilst Tulving (1968) has advocated a dichotomous theory of memory based on differing retrieval mechanisms and points to the limited capacity of immediate memory, he is not advocating a dichotomy of systems based on the limited retrieval capacity of STM. Thus in one paper (Tulving and Arbuckle (1966)) he suggests a limited storage capacity for STM whereas later he denies that any useful purpose is served by dichotomising on the basis of differing storage, as opposed to differing retrieval systems (Tulving 1968). Here he suggests that material may be added to STM, which later decays, leaving the original material still in storage. The decay of added material may be responsible for rapid forgetting in STM.

Tulving goes on to suggest that the use of more efficient retrieval cues may be responsible for reminiscence effects in LTM, a position similar to that of Brown (1959) and Peterson (1966c). Tulving's theory is obviously difficult to classify as being purely storage-decay theory, or purely a retrieval deficit theory, and whilst his theory will be criticised in Chapter 12 as lacking empirical support, it is necessary to note at this stage that he is not advocating a dichotomy, on the basis of the limited retrieval capacity hypothesis outlined above. This said, the following quotations taken from his paper "Theoretical issues in Free Recall" appear appropriate. P 13 "I prefer the view that all input information is stored in the same unitary storage system, whatever its nature, and that differences in recall of early, middle and late input items" (which he earlier argued suggest two types of recall mechanism) "reflect primarily differences in accessibility of these items." (i.e. retrieval) P. 21. "The limited capacity of immediate memory is one of the basic puzzles......." There is a contradiction, in fact, between regarding immediate memory as having limited retrieval capacity, and regarding the different sections of the serial position curve as indicating two dichotomous memory mechanisms, in which the last part of the curve represents output from STM. This is because the percentage of items retrieved from the recency part of the curve is greater than is the percentage retrieved from the middle section of the curve. Differences in accessibility there may be, but it is certainly not in the direction of a dichotomy between unlimited capacity of LTM and limited capacity of STM. Nevertheless, as Tulving clearly regards differences between STM and LTM to lie on the retrieval side, and as he clearly regards STM as having limited capacity, the implication that he regards STM to be limited with respect to retrieval unlike LTM is reasonably clear. Indeed, to talk of the limited capacity of immediate memory is to imply that LTM is relatively unlimited.

In so far as it is maintained that LTM has unlimited capacity relative to STM, as far as retrieval is concerned, this is true only in the trivial sense that there is less to be retrieved immediately than in the whole life history of an individual (LTM). But then it would be true to say that retrieval of events over a week is limited relative to the whole of LTM, without this entailing, or even implying, a dichotomous theory. of memory.

The limited capacity to Retrieve.

At first sight it might seem that the objection raised against the limited retrieval hypothesis, as a basis for dichotomising between STM and LTM, might be true of storage also. There is however, an essential difference between a limited storage and a limited retrieval hypothesis; the latter allows that all material is stored, in which case, as was pointed out, a dichotomy based purely on the limited retrieval capacity hypothesis is empirically untenable. On the other hand, the storage capacity hypothesis claims that there is a limited capacity to store material, thus if material is not stored in STM due to limited storage capacity, presumably it cannot be stored in LTM. This fits in with the empirical data to the extent that the forgetting curve falls off over time. Thus if only 10 items can be recalled in STM out of a list of 60, then after a period of an hour or so, 10 or fewer items are normally recalled. On the other hand the amount of material which is well learned is almost infinite, and there seems no limit to the amount of material which can be added to this stock. Thus whilst supra-span material which is newly taken in is liable to rapid forgetting which is due to lack of storage after the capacity has been reached, an almost infinite amount of material can be stored in LTM, according to the theory. In other words, if there is a limitation of storage in STM of A words of a list of A plus B words, the storage theory is not expected to require evidence of storage of A plus B words, as is the limited retrieval hypothesis, but only evidence of A plus C items, where C items are previously well learned items.

Tulving's dissatisfaction with this storage hypothesis is not, however, unjustified, in that reminiscence effects, where items not immediately recallable are recalled after a period of time, are extremely awkward for an STM limited capacity storage theory. An item not immediately recalled is presumed forgotten when assessing limited storage capacity; if it is recalled at a later time it must presumably have been stored, throwing doubt on the accuracy of the measure of limited storage capacity. As noted previously, Tulving found only 50% of items common to three successive retrieval trials, throwing considerable doubt on the accuracy of <u>any</u> measure of limited storage capacity. Peterson (1966) like Tulving, uses the reminiscence effect to defend a dichotomous theory of memory, claiming that this reminiscence shows a switching from one retrieval system to another. Essentially his theory assumes storage of all items later retrieved, and like Tulving throws doubt on the veracity of limited storage in STM. Objection is also raised against the memory span showing capacity of STM storage through experiments showing greater storage than is revealed by memory span methods. Harrison (1967) quotes a study in which a subject recalled 16 values of attributes in a list presented in 4 seconds, and concludes that therefore more is stored than is recalled. Bahrick (1969) has shown substantial retention by prompted recall and Loess and Harris (1968) in similar vein, note that where items which are presumed to be in STM are recallable with one method but not with another, it means that considerable attention should be paid to the method of recall when theoretical statements are based on recall data. Tulving and Pearlstone (1966) too have shown increased recall as a function of cueing with a category word and conclude that inferences about "what is available cannot be made on the basis of what is accessible". Nevertheless, it is possible to argue that these are practical problems involved in accurately assessing storage capacity, and whilst a serious problem, does not rule out the possibility that there is a limited storage capacity somewhat (indeterminately!) larger than obtained by normal recall procedures. Where later evidence of storage is produced, one presumably must argue that the immediate recall failure is due not to storage failure, but to retrieval failure, a somewhat dangerous argument in that it can so easily be argued that perhaps all rapid forgetting is due to retrieval failure. Indeed as Schonfield and Robertson (1966) and others, point out, we make all our inferences about memory on the basis of what is and what is not retrieved. Thus one cannot prove forgetting is due to storage or processing rather than retrieval defect. In the last analysis, then, it can be argued that the limited storage capacity hypothesis is unprovable.

Storage capacity and the immediate memory span

As Adams notes, the usual method of assessing the limited storage capacity of short term memory is the conventional memory span experiment first investigated systematically by Jacobs as long ago as 1881, in which, following the single presentation of a series of items, perhaps digits, subjects are required to recall them immediately in their correct order. In a typical experiment a subject will be able to recall about 7 digits without error (Miller 1957). Above the memory span, items are rapidly forgotten, and Conrad (1960) reports a rapid fall in the memory, immediately the memory span has been reached. However, the requirement of correct order is not the limiting factor for memory span, or at least the only limiting factor, in that in free recall experiments, recall drops off rapidly once the memory span has been reached (Murdock 1960). Thus one cannot distinguish between free recall and order recall in considering the problem of rapid supra-span forgetting. As rapid forgetting occurs for supra-span items in both conditions, both must be considered as essentially problems of STM.

As noted earlier (Chapter 4) the rationale for presuming that the memory span defines the capacity of STM rests on two factors, rapid supra-span forgetting and the fact that memory span items are themselves subject to fairly rapid forgetting, the example of the telephone number rapidly forgotten after use is often used to illustrate this latter rapid forgetting (e.g. Hunter (1964)). That this rapid forgetting of memory span items is the criterion by which it is decided the memory span describes STM can be appreciated if one considers the theoretical interpretation of the memory span, were the memory span items always recallable after a period of weeks e.g. if one did not, for instance rapidly forget telephone numbers. It could then reasonably be assumed that the memory span represented material in LTM.

Essentially then, the explanation of supra-span forgetting in terms of limited capacity to store information is the basis of the limited storage capacity hypothesis. Thus whilst some psychologists e.g. Phillips et al (1967) appear to regard forgetting in the short term as due to displacement (i.e. lack of storage capacity), there is no incompatibility between this limited storage hypothesis and the hypothesis that items within the memory span are forgotten because of trace decay. It is however, necessary to show that supra-span items are forgotten because of lack of storage capacity. (It was noted earlier (Chapter 5) that one is dealing with the problem of forgetting , rather than non acquisition once the memory span has been reached, as the evidence of Conrad (1960) shows.)

One of the attractions of looking at the memory span in terms of limited storage capacity comes from analogies with computer systems where buffer stores are used to hold information briefly. These are of a push down nature, such that each item coming in displaces an item already in store. Atkinson and Shiffrin (1968) have suggested this model for human memory and it appeals to Norman (1968) too, on the grounds of usefulness. It is, however, interesting to note that Feigenbaum (1967) recently described a computer which did not have a buffer store. This computer worked well until the information was fed in at a greater rate than the computer could deal with, when there was a failure to process material adequately, resulting in the equivalent of retrieval breakdown. It is reasonable to point out that the same sort of behaviour occurs in humans when the memory span is reached. This of course does not prove there is no buffer store, but it does highlight the dangers of arguing for the existence of mechanisms by analogy - one can usually find an analogy to suit most situations.

Apart from supra-span forgetting being questioned as due to lack of storage capacity (e.g. by Melton (1963) and Brown (1958) noted earlier) there is considerable question even amongst dichotomous theorists, as to whether the memory span items measures purely short term memory. Sanders and Schroats (1968) for example suggest that the memory span contains an element of LTM because parts of the memory span are able to resist forgetting better than others. Broadbent (1967) notes that "even in memory span there is long term memory, in that letter frequency affects retentiom". This of course has been known for a long time. Thus Blankenship (1938) and Hunter (1966) note differences in retention with different materials. In a typical experiment, such as Crannell and Parrish (1957) meaningful words were found to have less of a span than digits. Other experimenters have found digits superior to letters (Bremner 1940).[∆] If there is a doubt as to the extent to which memory span is a pure measure of capacity of STM, it seems difficult to see how even approximate limits of STM capacity can be measured and, how, therefore a dichotomy of memory systems can be established on the basis of the limited storage of hypothesis, at least if the memory span is used as a measure of capacity.

Further criticism of the use of the memory span as a measure of limited storage capacity comes from Neisser (1967). He points out that the memory span may have no special status in that sub-span units are also rapidly forgotten under certain conditions of measurement and that a discontinuity between material "within" and exceeding the

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∆ Warrington et al (1966) claim to have shown that memory span for digits and letters is not different when the probability of occurrence of each is taken into account.

memory span disappears with certain measures of memory.

Recognition v. recall as a measure of retention

Finally, the limited storage capacity hypothesis has been questioned by psychologists who, using recognition rather than recall as a measure of retention, have shown evidence of a large capacity to store incoming information to the extent that perhaps storage capacity in STM is not limited, provided one uses the appropriate measure of capacity. Thus Nickerson (1965) found 87% recognition following the presentation of 200 photographs of complex meaningful material. As presentation rate was one item every 5 seconds, it is possible theoretically, to claim that there was sufficient time to transfer the material from STM to LTM. Shepard and Teghtsoonian (1961) found retention after 60 interpolated items, and Shepard (1967) found 90% retention in an experiment involving the successive presentation of 540 words. In both Shepard's experiments presentation was self paced, however, leaving open the theoretical possibility of an interpretation in terms of LTM. Again, because so many stimuli are involved in Shepard's 1967 experiment it might be claimed that the total presentation time exceeds the bounds of what one might term an STM experiment.

A final objection to Shepard's experiment requires special attention. One of the methodological problems in testing retention by recognition is the increase in response bias which is found towards the end of a list using multiple choice testing, i.e. there is an increase in false-positive recognitions. Shepard and Chang (1963) demonstrated that this problem could be eliminated by using a forced choice technique, in which an old and new item are presented simultaneously. As was noted in Chapter 5, however, the forced choice technique is a special case of multiple choice testing, differing from normal multi-choice testing in that there is only one distracter. In using this technique therefore, Shepard is open to the objection that high recognition rate may come, not from recognising an old item as old, but from recognising a new item as one which is new. Thus if given the sequence 832964, a subject can readily say that X was not in the sequence; given the forced choice 2 or X, a subject, by identifying X as not previously presented, would choose "2" as the old item, whether he had retained it or not. (It might of course be countered that to identify an object as new, one must have retained something of all the old items. If one uses this argument, however, evidence needed to claim retention for "N" items is evidence that a subject can identify one item as new. It is not an altogether unreasonable suggestion).

The Present Experiments

Aim of the Present Experiments

The present experiments are intended to explore the storage capacity of STM taking into account the objections raised earlier against the experiments on recognition.

This was done in the first experiment by presenting words at the rate of one per second, approximately, for a total time of two minutes eight seconds, and testing for recognition by presenting old and new items successively but in random sequence, rather than simultaneously, and correcting for response bias by subtracting false positives from correct identifications. Whilst there is evidence (Norman and Waugh 1968) that where N> 10 recognition is independent of both stimulus and test position (using the same technique as in the present experiment), this is not important for present purposes. Even if response bias were to operate in the way that Shepard and Chang (1963) suggest, i.e. by an increase in false positive scores, the effect of taking wrong answers from correct responses would be to reduce the retention score, making the estimate of retention a conservative one.

Whilst the aim of the experiment was to take account of possible objections to earlier experiments in recognition within the framework of showing the limits of capacity of STM, it was also intended to show that even when these objections are met, recognition is extremely high. As was noted in Chapter 5, infrequent words are usually (though not always) better recognised than frequent words. For this reason infrequent words, (according to Thorndike and Lorge (1944)) were chosen for the experiment. The experimenter's intuition, that meaningful infrequent words would be better recognised than meaningless ones resulted in choosing words which would be known to the student population at large (e.g. Bagpipe). (An experiment by Allen and Gorton (1968) later substantiated the intuition).

A second experiment was carried out to show that the initial experiment, described above, must be considered as a short term memory experiment. It consisted of requiring recall immediately after the presentation list described above, followed about 30 minutes later by the same recognition test as in the first experiment

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Footnote: The obvious methodological objection that recall facilitates later recognition e.g. Postman et al (1948) Brown and Packham (1967) or alternatively retards it (Hannawalt and Tarr (1961)) is not relevant with the context of this experiment in that even if recall facilitates later recognition, it can hardly lead to evidence of retention of what is not there.

METHOD

Experiment One

Subjects 20 undergraduates and postgraduate students from the University College of Swansea.

Materials A list of words (Presentation List) of frequency one per million according to the Thorndike-Lorge word count (1944) i.e. infrequently occurring words, whose meaning, however, would be known, to a student population e.g. Barnacle, Bagpipe, Adage. All words were of at least two or three syllables, and were recorded on magnetic tape at an average rate of 1.1 words per second. A second TEST list was also constructed, consisting of 60 words from the presentation list (every second word on the presentation list was included on the test list) and sixty new words of the same frequency as the presentation list words. The words were arranged randomly.

Design The subjects, who were tested individually, or in groups of two or three, were asked to listen passively to the presentation tape and to make no attempt to learn the items. As soon as the presentation tape was finished, items on the test list were presented successively, and the subjects were asked to indicate whether the words were old or new, andtheir degree of confidence in their decision. The ratings Y3 and N3 indicated that they were certain that a word was old or new respectively. Y2 and N2 indicated that they were quite confident but not certain, that the word was old or new respectively and Y1 and N1 indicated that they thought the balance of probability was in the appropriate direction. There was no neutral rating.

Experiment Two

Subjects: 19 undergraduate students at University College of Swansea, who had not acted as subjects in Experiment One.

Materials: The presentation and test list were, as described in Experiment One. The presentation list was recorded with greater clarity than in Experiment One, on magnetic tape at an average rate of 1.1 words per second.

Design: The experiment was divided into two parts. Immediately after the presentation tape had finished, subjects, who had been asked to listen passively to the tape, were asked to recall as many words as possible. Subjects were allowed to continue with this task until either they claimed they could not recall any more words or 30 seconds had elapsed from the time of writing the last word, with no sign that they could recall any further words. Subjects than took part in a psychology tutorial during which each was asked at least one question of relevance to the tutorial topic. After a minimum interval of 30 minutes subjects were given the same recognition task and test list as in Experiment One.

Results:

In Experiment One, the mean number of items retained was 50.10 for the 20 subjects. The range of the number of items retained was 18 - 76. If one removes from the sample four biased subjects with a

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Footnote: The word lists used in the experiments are contained in Appendix 1a and 1b.

TABLE ONE

Experiment One

Number of items recognised immediately after presentation

(for 20 subjects)

No. correct Yes responses		Errors of Inclusion (False Positives)		Items retained	
MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
1		2		col (1-2) x 2	
42.95	7.21	17.90	11.02	50.10	15.72

TABLE TWO

Experiment Two

Number of items recognised after 30 minutes

(19 subjects)

No. correct Yes responses		Errors of Inclusion (False Positives)		Items retained	
MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
38.74	5.03	19.84	6.73	37.79	12.52

TABLE THREE

Experiment 2A

Number of items recalled immediately after presentation

(for 19 subjects)

MEAN No. of items correctly recalled	S.D.
10.53	2.72

high response bias (i.e. with YES responses greater than 75%) the mean is 55.12. In Experiment Two, the mean number of items recalled immediately after presentation was 10.53. The mean recognition rate after 30 minutes was 37.79.

Discussion

It must be admitted that these results are hardly surprising. Adams (1967) points out that many studies show recognition superior to recall by a factor of three. Because of differences in the quality of the tapes in Experiment 1 and 2 it is not possible to conclude that recognition may have been facilitated by recall, making any conclusions of the nature of the exact superiority of recognition over recall tenuous.

The importance of the present results lies not in showing the extent of the superiority of recognition over recall but in the problems posed for a limited storage capacity hypothesis. Experimental disproof of the hypothesis is, of course, hampered by the imprecise formulation of the word 'limited', since Adams (1967) is thinking in terms of a recall of memory span of some 7 - 9 items, it is obvious that the number of items stored in both Experiment One and Experiment Two is considerably in excess of this. Perhaps a more satisfactory approach is to reformulate the problem of limited storage capacity. If one continues to put in information for what is considered to be short term memory, say two minutes, (An arbitrary figure of course, as there is no agreed time limit on STM i.e. there is no agreement as to what constitutes rapid forgetting) and one can produce evidence to show that storage is of a high order and that there is no evidence to show that what forgetting there is, is due to factors other than interference or trace decay, then one has good reason to question that storage capacity is limited, indeed one has no basis upon which to establish a dichotomous theory of memory on the basis of the limited capacity to store incoming information.

As table one shows, there is a high order of retention under the conditions of experiment one outlined above, and the evidence of retention produced must be considered the lowest estimate of information in store, as there is ample opportunity for intra-list interference, or trace decay, which will reduce the amount of information actually retrievable. These results indicate that, unless recognition is irrelevant as a measure of capacity, the evidence for establishing a dichotomous theory of memory on the basis of a limited capacity hypothesis is at the very least, equivocal. It is true, of course, that there is nothing magical about 40% retention as a disproof of limited storage. But what this data has shown is that a large amount of forgetting which was previously attributable to limited storage capacity (i.e. those items not recalled once the memory span has been reached) cannot unequivocally be accounted for in such terms. It is possible that what forgetting there is, is due to interference or trace decay rather than lack of storage capacity. Again, it is not being claimed that given two systems of memory, one cannot account for the data, just that the data prevent one from establishing a dichotomous theory of memory based on a limited capacity hypothesis.

The critical question, of course, concerns the relationship between recognition and recall. If, for example, all forgetting is due to interference as described earlier e.g. Melton (1967a) and recall is degraded to recognition through interference, then there is no forgetting due to limited storage capacity and the basis for dichotomising is at an end. Even if only the items recognised can be shown to indicate the storage of items, this will make it that much more likely that storage capacity is not limited in that rapid supra-span forgetting to a large extent will not be accountable for in terms of lack of storage space. This is the point of the present experiment - not that it will provide a conclusive disproof of limited storage capacity, but that it makes even more unlikely that a dichotomous theory of memory can be established on the basis of this type of evidence. As was noted in Chapter 5, whilst various possible relationships between recognition and recall have been postulated, the most parsimonious assumption at present is that they both involve the same memory system.

Again it was argued in Chapter 5 that material which could be recognised was originally recallable, in normal memory experiments at least, so that the relationship between recognition and recall was of such a nature that a degredation of the original trace made recognition only, possible, where previously recall was possible. The central problem then becomes, what is the nature of this trace degredation that leads to recognition only being possible?

Three general causes of forgetting were postulated in Chapter 5.

1. There may be autonomous decay of the trace for reasons unconnected with experience.

2. There may be forgetting due to trace unavailability rather than storage loss i.e. "classical" interference theory.

3. There may be forgetting due to experiential factors causing trace degeneration e.g. displacement or overwriting.

As will be seen presently, for the purpose of the present analysis it is useful to divide the third category into theories which postulate that interference causes trace decay, and other theories postulating trace degeneration as a consequence of experiential factors. The implications of the various possible causes for the limited storage capacity hypothesis are noted below.

1. If forgetting is due to trace unavailability i.e. retrieval deficit - the limited storage capacity hypothesis is at an end. Interference theory, as was noted previously, assumes that material once in store is there permanently. If such is the case, material even in short term memory is always in store and presumably being added to by incoming information. It cannot therefore be regarded as having limited storage capacity.

2. If forgetting is due to autonomous trace decay, then the limited storage capacity hypothesis is at an end. Autonomous trace decay theory does not claim a limit in storage capacity; the limit on retention is due to failure to prevent the traces decaying past the point of recall. Evidence that an item had been stored, even with recognition measures, therefore indicates that storage space was available for that item, thus recognition of 50 or so items indicates storage of at least that number of items.

3. If forgetting is due to interference causing trace decay, the limited storage capacity hypothesis is at an end. This is because the limit on taking in incoming information is not in terms of storage capacity; presumably if a test could be devised such that interference was completely absent, an unlimited amount of material could be stored.

4. If forgetting is due to displacement or compression, then the

limited storage capacity hypothesis may be held. However, unless it can be proved that displacement or compression is the cause of rapid forgetting, at least of the supra-span forgetting of Experiment 1, and be shown not to be the cause of forgetting over days and weeks and years, then it is impossible to establish a dichotomous theory of memory on the basis of the limited capacity hypothesis. This is because holding a displacement hypothesis assumes limited storage capacity. If storage capacity in LTM is also limited (ie. assuming displacement in LTM) then one cannot hold a dichotomy on the basis of the limited STM storage capacity and unlimited LTM storage capacity.

The evidence on the nature of forgetting is dealt with in Chapter 6. As the review of the evidence showed, it is by no means clear what the cause of forgetting is, either in the short or in the long term. This is as true of displacement as a cause of short term forgetting as it is true of other theories. Indeed it was noted that evidence of associative factors causing short term forgetting, and of repetition effects increasing short term forgetting, is extremely embarrassing for such a theory.

If it is accepted that the cause of forgetting is not yet known, then of course, whilst the evidence might be compatible with a limited storage capacity hypothesis, a dichotomous theory cannot be established on the basis of our limited capacity to take in new information. It is possible that short term forgetting is due to factors such as interference or decay, which do not imply limited storage capacity. The evidence of this chapter is that a limit in storage capacity is unlikely because of the evidence of a large number of items stored, following a single presentation at a speed of 1.1

items per second.

It is interesting to note, in conclusion, that a large number of dichotomist theorists consider that recognition and recall differ in terms of retrievability of material, not storage. (Kintsch (1968) Norman (1968), Wickelgren, (Norman and Wickelgren (1969)) have all suggested retrieval differences between recognition and recall.) For these theorists, at least, the evidence of this Chapter is problematic.

Summary of Chapter

It was first noted that any attempt to establish a dichotomous theory of memory on the basis of the limited capacity to retrieve newly presented material, demands a demonstration that STM has limited storage capacity. Limited processing capacity may be interpreted in terms of a single memory system, and the hypothesis of limited retrieval capacity of STM as opposed to unlimited retrieval capacity of LTM for any given set of items, falls in the face of the empirical evidence.

The main source of evidence for the limited storage capacity hypothesis comes from the conventional memory span experiments, in which rapid supra-span forgetting defines the memory span, the memory span being claimed to describe the limits of storage capacity of STM because it, too, is subject to rapid forgetting. In order to demonstrate limited storage capacity using memory span it is essential to show that supra-span forgetting, at least, is due to limited storage capacity.

There are however numerous objections to the interpretation of the memory span as showing limited storage capacity. These are now listed:

1. Supra-span forgetting might be due to rapid trace decay or to interference factors.

2. Reminiscence effects, where items not immediately recallable, are recallable at a later time, indicate that failure to recall an item does not indicate it is lost from store, indeed it is impossible to demonstrate, empirically, that items not retrieved are lost, whether later recall is possible or not.

3. Prompted recall techniques and cued recall techniques indicate that immediate recall does not indicate the extent of storage. Hence supra-span items rapidly forgotten may still be in store, making untenable the interpretation of such forgetting in terms of limited storage capacity.

4. It is even questioned by dichotomous theorists whether the memory span represents only output from STM, first on the grounds that some sections of the memory span are more resistant to forgetting than others, second, on the grounds that the nature of items affects the length of the span.

5. Sub-span units are rapidly forgotten under certain conditions, thus the conventional memory span may have no special status.

6. Recognition measure of retention show evidence of storage considerably beyond the memory span.

In our present state of knowledge, objection 1 on its own, prevents the establishment of a dichotomous theory on the basis of limited storage capacity whatever the basis of holding the hypothesis and whether recognition and recall are dichotomous states or not. Objections 2, 3 and 7 are positive objections in the sense that not only do they prevent the establishment of a dichotomous theory on the basis of evidence of limited capacity to retrieve newly presented material, they positively make it less likely that limited storage is the cause of supra-span forgetting. For this reason the author conducted the experiments on recognition, considering it important that minor theoretical objections to earlier work should be removed.

The First Experiment involved a recognition test after a presentation list of 120 words, presented at approximately 1 per second. The second experiment involved immediate recall from the list, towgether with a recognition test 30 minutes later. The results indicated that there was approx. 40% recognition in Experiment 1; 10.53 items were recalled and 37.3 items recognised in Experiment 2.

Basically the experimental results make it more difficult to hold that there is limited storage capacity by showing considerable retention amongst supra-span "forgotten" items. Perhaps the most likely relationship between recognition and recall, in terms of trace decay or interference, also makes the holding of a limited storage capacity hypothesis more difficult. Certainly the evidence for a displacement or compression hypothesis, is far from unequivocal. Even if there were evidence which supported a displacement or compression hypothesis in the short term, it would not be possible to establish a dichotomous theory of memory on this basis, until it could be shown that this was not the cause of forgetting in LTM also.

It seems clear that dichotomous theorists are far from establishing a dichotomous theory on the basis of the limited capacity hypothesis i.e. they are far from being able to claim that evidence of the limited capacity of the memory system to deal with incoming information is explicable only in terms of a dichotomous theory. The next chapter will be concerned to show that it is not at all clear that a dichotomous theory can even adequately handle the experimental evidence presented in this chapter.

CHAPTER 8

THE LIMITED CAPACITY HYPOTHESIS 2:

Introduction

The last chapter was concerned to show that a dichotomous theory of memory cannot be established on the basis of the limited capacity of subjects to retrieve incoming information, because this limited capacity is explicable in single system theory terms. Thus whilst one explanation might be in terms of two distinctive memory systems (i.e. the immediate memory capacity might be in terms of storage,) it might also be in terms of other factors which do not entail a dichotomous theory of memory. Indeed the last chapter showed that there was evidence of large amounts of stored information in immediate memory after the traditional measure of capacity had been used, questioning the assumption that the prima facie evidence is consistent with the limited storage capacity hypothesis (LCH)

It is however, one thing to prove that the evidence is insufficient to establish a dichotomous theory of memory on the grounds of LCH, quite another to show that the evidence is totally inconsistent with such a hypothesis. For this reason, the question of whether a dichotomous theory can be established on the basis of limited capacity, or whether the evidence is even interpretable in terms of a dichotomous theory, are treated in separate chapters. Thus the author is concerned lest some ingenious ad hoc assumptions, enable an interpretation of the experimental evidence to be made in terms of a dichotomous theory. These in turn might be used to refute the far more important argument of the previous chapter, i.e. the baby might be thrown out with the bath water.

Various arguments can be used to claim that the experimental evidence of the last chapter can be accounted for in terms of a dichotomous theory of memory; these are considered below.

1.. Information enters directly into long term memory store

The first possibility is that information enters directly into long term memory store, by-passing the short term memory store. This of course raises a fundamental problem for dichotomous theorists, the criterion under which it is claimed material is in one system rather than another. As has been noted in Chapters 4 and 6, rapid forgetting must be assumed to take place in short term memory if a dichotomous theory is to hold. To allow that items in Experiment 1 and 2a entered long term memory direct is to allow that rapid forgetting can take place in long term memory, as the recall of only 10.53 out of 120 items indicates. At the very least to take the position that items entered LTM direct, is to admit that rapid recall loss of digits is no criterion for establishing the limited capacity of storage of short term memory. The items may well enter LTM direct and be rapidly forgotten in that system. Indeed even failure to recognise digits may indicate only the extent to which rapid forgetting has occurred in LTM. It appears necessary therefore to regard the items recognised in Experiment 1 as residing in short term memory store, if one is not going to compromise the major criterion for deciding whether or not material is in STM, rapid forgetting.

If it is to be held, then, that the information in Experiment 1 enters LTM direct, on what grounds can one unequivocally maintain that any material does not enter LTM direct, making the postulation of a short term memory system redundant. (It is, of course unparsimonious to argue that a distinction must be drawn between serialised material and non-serialised material in considering the theoretical implications of the data presented, one has then to postulate two mechanisms for rapid forgetting as the evidence from this study is that even for non-serialised material, forgetting as measured by recall loss is rapid.

2. Information is transferred rapidly to long term memory.

If it is claimed that all material enters STM, where it is either lost or transferred to LTM rapidly, a central problem remains. Material which at one stage could be recalled in Experiment 1 is to a large measure only recognisable at the time of the retention test. The forgetting which results in recognition only being possible must however have taken place in STM; (rapid forgetting, as was previously noted, must be considered to take place in STM). This is not a very radical position for a dichotomist; many regard forgetting in STM to be due to some extent to trace decay, yet, it raises a very severe problem for the status of rehearsal if material which is presented at the rate of 1.1 items per second, and which then decays in STM such that it cannot be recalled, is rapidly transferred to LTM. Thus, if material cannot be recalled, it is difficult to see how it can be rehearsed, at least in the sense of some form of repetition, as it is commonly regarded, e.g. by Murdock (1967) Waugh and Norman (1965), and Norman (1969). These writers regard rehearsal as critical in transferring material from STM to LTM. It cannot however be critical in Experiment 1.

A second problem also presents itself - regarding rehearsal. Whilst it has been argued that delivery of two and three syllable words at the rate of approximately one per second cannot preclude the possibility of rehearsal of material as it comes in, it should be noted that this objection can be raised against many STM experiments using the same rate of presentation including many allegedly supporting dichotomous theory e.g. Baddeley (1966 b) presentation rate one per sec. Conrad (1964) letters presented at one every .75 sec. Cohen and Johansson (1967) digits presented at one per sec. to name but a few. Nor can speeding up of presentation rate control for the possibility of rehearsing material at the same rate as fresh material is coming in; one may have a shadowing phenomenon such that rehearsal can begin before the item is wholly in. Indeed if this phenomenon is not occurring it becomes almost impossible to rehearse multi-syllable words presented at one per sec.

The problem of rehearsal was discussed in Chapter 6, where it was noted that the function of repetition in increasing retention was open to question. It appears more likely that the opportunity for reorganising material is critical in improving retention. Whilst it is not being claimed that such processes did not operate in the present experimental situation, it is claimed that they do not take the form that is claimed by those holding a dichotomous theory, namely in terms of active repetition of items. Any process which might have been taking place was of such a nature that it could not reasonably be described as rehearsal; at best it must have involved some automatic integration of new and old material, without the intervention of a control mechanism. Yet to hold as critical to a theory, a process which can have no behavioural effects that distinguish it from other processes which equally well account for the data (e.g. the integration of material with the pre-existing cognitive framework), is clearly unsatisfactory.

It may be that rehearsal is critical in transferring material from STM to LTM, but not if by rehearsal is meant the overt or covert repetition of an item.

In summary then, it is quite clear, that items of experiment 1 can be claimed to be in LTM only at the price of denying any critical part to "rehearsal" in the transfer process. This is a somewhat difficult position for a dichotomous theory to be in as it allows transfer to be an automatic process. This makes untenable the intuitive basis for a dichotomy, that there is a decision mechanism as to usefulness or otherwise of material which is then discarded or transferred. Rehearsal, as Tulving and Madigan (1970) have pointed out, may well lead to better retention because it aids reorganisation within the cognitive framework, not because any transfer of material from one system to another is in evidence. A methodological problem must also be faced if it is claimed that material recognised in experiment 1 is in long term memory (if it is claimed to be in short term memory then the limited storage capacity hypothesis is of course compromised). To be in long term memory the items in experiment 1 must have been rapidly forgotten to some extent, transferred and then retrieved from long term memory within the space of 0 - 4 minutes. It is extremely difficult to see how one can distinguish this hypothesis from one which claims that rapid forgetting took place in "long term memory". In other words, a theory which postulates that items can be rapidly copied into long term memory from short term memory, in the absence of rehearsal, such that material can be recognised, but not recalled, seems indistinguishable from a theory which claims that all material enters

LTM, where rapid forgetting of some items takes place such that recognition only is possible, where once recall was possible.

3. Short and long term memory can exist simultaneously

It might be argued that STM and LTM can exist simultaneously and in experiment 1, one is measuring a composite of output from STM and LTM. (This is the position, for instance, taken by Waugh and Norman, 1965). However as the limit of STM is claimed to be about 4 - 6 items, the vast majority of items must again be assumed to be in LTM. Again the problem of transfer of material from short to long term memory in the absence of rehearsal is posed, as is the methodological problem raised in the last section.

4. Recognition does not indicate unlimited capacity

It might be argued that recognition involves compression of items in "short term memory" andthat when STM is overloaded there is a loss of some information from each item. Thus whilst one may be able to store a great number of items in STM, this is on information which is equivalent to allowing for recall of only a few items. For example in experiment 1, the recognition of 50 items is based on the same amount of information as the recall of 10.53 items. This suggestion is put forward by Murdock (1968 b).

As was noted in the chapter on recognition and recall (Chapter 5) the fact that 27 extra items could be recognised after a recall task is a refutation of this position. Insofar as a dichotomy is claimed on the basis of compression being a short term memory phenomenon (it can hardly be claimed to be an LTM phenomenon if LTM has unlimited capacity), it must be shown that forgetting after 30 minutes or so, such that recognition only is possible where recall waspreviously possible, is not due to compression. There appears to be no empirical basis upon which such a distinction can be made.

Finally a compression theory is faced with the problem of rehearsal in explaining the data of experiment 2. If only 10 - 53 items are immediately recallable and other items which are recognised immediately are in STM, how are an additional 27 items retrievable from "long term" memory after 30 minutes? As was noted previously, items which cannot be recalled presumably cannot be rehearsed. How could these items therefore, which were recognisable only in STM, be transferred to LTM if rehearsal is critical in the transfer process, as Murdock (1967) claims.

Summary of chapter

The main points of this chapter can now be summarised.

The evidence and discussion of the previous chapter (Chapter 7) might be questioned on the grounds that Experiments 1 and 2 a, b, discussed in Chapter 7 are interpretable in terms of a dichotomous theory. It is noted that whilst this may be so, that is far removed from establishing a dichotomous theory of memory. Certain difficulties are then noted even in interpreting the evidence of Chapter 7 on the basis of a dichotomous theory. These are:

1. It cannot be claimed that all items have entered LTM direct, without undermining the basis for a dichotomy between short and long term memory, rapid forgetting being essentially a short term memory phenomenon. Thus if all items entered LTM direct, all but 10.53 can be regarded, as, to some extent, being rapidly forgotten.

2. If it is claimedthat the items recognised in experiment 1 have been rapidly transferred from STM to LTM, then rehearsal, which is

often claimed to be critical in the transfer process, cannot be regarded as being critical in this experiment. At best an automatic transfer process can be postulated, which strikes at the intuitive basis for postulating a dichotomous theory.

3. The view that recognition scores do not indicate greater storage than recall scores is refuted as recognition exceeds recall after the recall test. Thus more is stored than is available through recall test procedures.

Finally it should be noted that this chapter is relatively unimportant. It does not matter too much if the experimental evidence is compatible with a dichotomous theory. What is important is that a dichotomous theory cannot be established on the basis of empirical evidence which claims to show the limited capacity to store incoming information. As the previous chapter showed, this is not the only interpretation of the data, indeed it is not the likely interpretation of the data in view of the large number of items which could be recognised following a single exposure of items at 1.1 per second. A single system theory can handle the empirical data. This is what is important.

CHAPTER 9

SEMANTIC AND ACOUSTIC CODING IN SHORT AND LONG TERM MEMORY

Introduction

Adams (1967) considers that a major line of evidence for a dichotomous theory of memory comes from studies (e.g. Baddeley (1966b) and Wickelgren (1965a) which indicate that acoustic confusion occurs in short term memory, whereas semantic confusion occurs in long term memory. From this it is inferred that STM storage of information is in terms of an acoustic code, in LTM it is in terms of a semantic code. Many psychologists apart from Adams were, until recently at least, also willing to draw a distinction between short and long term memory, on the basis of this type of evidence. Thus Baddeley (1966a) P 302 "Unlike STM, LTM proves to be impaired by semantic similarity, and (1968) P 162. "Further evidence of two separate processes is provided by the results of Baddeley (1966) in which learning word sequences was influenced by acoustic confusion but not semantic similarity, when recall was immediate. When recall was delayed for one minute, however, the position reversed and semantic similarity became crucial while acoustic similarity had no effect."

Norman (1969) also makes similar claims - P 127 - "In later experiments (e.g. Baddeley 1966b) it has been shown that LTM is affected by semantic similarity of the learned items but not by acoustic similarity. Thus it appears that acoustic coding is a temporary phenomenon restricted to primary memory." Again Wickelgren (1969 b) P 127. "The evidence from studies of human memory strongly supports the hypothesis that long term verbal memory is in a semantically encoded system ....whilst short

term verbal memory is predominantly encoded phonetically."
Two sub-problems concerned with semantic and acoustic confusion can be identified. First, what do these confusion effects involve and what can legitimately be inferred, assuming their empirical veracity? Second, is the evidence upon which a dichotomy of operations is based, adequate? In this chapter it will be shown that not only is the evidence upon which a dichotomy of operations is based inadequate, even the production of adequate evidence could not be interpreted as entailing a dichotomous theory of memory.

It is not too clear what those who argue for a dichotomy of memory systems are claiming when a dichotomy is made on the basis of different coding systems. Presumably what is meant is that relationships among different items of information in STM are in terms of an acoustic dimension, whereas relationships among items in LTM are in terms of meaningfulness. As operationally the inferences are normally made on the basis of confusing items which either sound alike or mean similar things, e.g. Baddeley (1966a, b) this indicates that acoustic interference in STM involves the rapid forgetting of items stored in an acoustic relationship with each other, whereas semantic interference effects involve the slower forgetting of items stored in meaningful relationship (or associative) to each other. (Presumably dichotomous theorists account for the slow nature of forgetting of semantically related items, to their not being in a semantically related system for a period of time after presentation.). The storage in terms of acoustic relationship must decay rapidly, if it is to be claimed an STM characteristic, on the other hand, forgetting of a semantic nature cannot be said to have taken place within the time period described by STM as this would allow one to claim that rapid forgetting of semantic material had taken place. Empirically, then, a disproof of a dichotomy based on semantic and acoustic coding in LTM and STM involves evidence of semantic processing within the time limit of STM and evidence of acoustic coding outwith the time limit described by STM. These are now considered in turn below.

Short Term Memory

Three workers were initially involved in the experimental demonstration of acoustic confusion in STM, Conrad (1964) Baddeley (1966 a, b) and Wickelgren (1965 a, b, 1966). Conrad (1964) who, it must be stressed, has at no time held a dichotomous theory on the basis of differing interference effects, showed rapid forgetting of letters which were acoustically related, to the extent that letters which sounded alike were confused more than those which did not. His experimental proceedure consisted of presented sequences of six letters, in which the population of letters was confined to two sets of acoustically similar letters e.g. PVC, MNF. After presentation, recall was asked for immediately, and it was found that where errors occurred these were of an acoustic nature i.e. errors were acoustically related to the original presentation. Conrad was concerned at the implications of these results for a trace decay theory, and made no statement about evidence for a dichotomous theory of memory on the basis of his evidence, indeed he specifically notes that Woodworth (1938) has provided evidence of acoustic confusion in LTM. Further he notes that acoustic confusions for this type of material were not surprising (in spite of visual presentation) in that the type of material used is normally dealt with acoustically.

Baddeley (1966a, b) has taken a different line from Conrad in that he interpreted his findings in terms of a dichotomous theory of memory.

Baddeley (1963, 1966a) presented subjects with sequences of five similar sounding words, e.g. Man, Mad, Map etc., at a rate of 1 word per second and contrasted the correct recall of such sequences with similar length sequences of semantically related words and non-related words. He foundconsiderable evidence for acoustic interference, and also statistically significant effects of semantic interference. From these results he concludes that STM and LTM use different coding systems (p 302. It must be admitted that he later states that what constitutes the difference between STM and LTM time in store, number of repetitions or coding system employed, remains to be seen. Elsewhere, however, he isless cautious, (1968) and as noted above, concludes that the evidence supports a dichotomy on the basis of acoustic confusion characteristic of STM and semantic confusion of LTM. The further inference is that STM uses acoustic coding and LTM semantic coding only. More recently, evidence claimed to support the hypothesis that acoustic coding is confined to short term memory comes from the studies of Craik (1968) and Kintsch and Buschke (1969). Both studies utilised free recall techniques and showed that acoustic confusion effects were confined to the recency part of the serial position curve, claimed by dichotomous theorists to represent basically output from an STM store.

Even were the evidence produced to indicate that semantic and acoustic coding are dichotomously divided by time, it is dubious whether the hypothesis of STM being an exclusively acoustic system stands up against the empirical evidence of visual storage.

Thus leaving aside evidence that in STM confusion may be articulatory and not acoustic (Hintzman 1967), evidence of visual storage in STM comes from such studies as those of Ross (1969). Ross found that deaf 'S's are not necessarily inferior to hearing 'S's when visual sequences are presented, and suggests that the translation of visual sequences into auditory storage is a more common strategy, not a necessity. Conrad and Rush (1965) too provide evidence that acoustic factors are not operating in deaf subjects. Their subjects did not make errors of an acoustic nature where non deaf subjects do.

Of greater importance, however, are the large number of studies which indicate semantic processing in short term memory. An early example of such experimental evidence is in the "classical" paper of Wickens, Born and Allen (1963) who showed release from Proactive Inhibition (PI) by switching from one category of items to another. Whilst these authors were concerned with PI release, it is quite clear that this release depends on the subject perceiving the new category (e.g. letters) as one which semantically (or at least associatively differed from the previous one. Without semantic processing such release from PI would not have been possible.

A second experiment which showed statistically significant semantic interference effects is that of Baddeley (1963) and in view of this it is most surprising that he is willing to dichotomise on the basis of differing interference effects. Further papers showing semantic processing in STM are these of Barkowski and Eisner (1968) who find degree of abstractness a major variable in STM retention. Dale and Gregory (1965) who found interference effects for paired associates in STM; Calfee and Peterson (1968) who found that list organisation facilitated memory; Erhard (1968) found superior retention of familiar meterial over unfamiliar material; Henley, Nöyes and Deese (1969) like Calfee and Peterson, found that semantic structure facilitated recall in STM. Loess (1968) showed semantic interference effects in a PI design. He presented 3 item sequences of semantically related categories, followed by interpolated activity; after this interpolated activity a further 3 item sequence was presented which was semantically related to the first sequence. Semantic interference effects resulted. Murdock and Van Saal provided evidence of semantic processing by showing transformation errors are greater where category classes are similar in STM experiments. Turnage (1967) found that high and low frequency words were forgotten at a different rate over a 30 second interval. He interprets the results as showing that in STM, like LTM, forgetting is due to PI. Two papers by Wickens (Wickens and Clark 1968, and Wickens, Clark Hall and Wittlinger 1968) show semantic processing in STM. In the first experiment, evidence of release from PI is produced using words of a different semantic class. In the second experiment, release from PI was demonstrated switching from adjectives to verbs. Wickens et al (1968) claim the experiment was not adequate as the possibility existed that the release was due to semantic factors. When these semantic factors were removed the switch from adjective to verb did not result in release from PI. It might be suggested that even if the results had been due to a switch from adjective to verb, this would have indicated processing of a semantic (as opposed to acoustic) nature. Finally, as far as this review is concerned, using a Peterson and Peterson type design, Whimbey and Fischof (1969) found that PI effects resulted from semantic similarity.

Whilst these studies indicate semantic processing in STM, Posner (1967) has noted that there has been a universal failure to produce evidence of RI as a result of semantic similarity, and Glanzer et al (1969) having failed to produce RI using semantic similarity, concludes that forgetting is not due to the nature of interpolated items, merely the number, despite the considerable evidence reviewed in Chapter 6, showing the contrary to be the case. Nevertheless evidence has now been produced by Corman and Wickens (1968) using a Peterson and Peterson design, which indicates the semantic confusion in short term memory.

Whilst almost all the studies just quoted in support of the view that semantic processing occurs in STM, have been recall studies, there is evidence of semantic processing in recognition studies. Thus one of the studies quoted in Chapter 5 (Young et al 1968) indicates semantic processing in STM. Evidence that recognition memory involves semantic processing in STM is not only important as evidence of semantic processing in STM per se, but also for the implications it carries for a dichotomy between recognition and recall. First a demonstration of the effect of semantic factors in STM recognition makes it impossible to hold that recognition memory is somehow a literal perceptual trace. Semantic processing indicates that integration has taken place between incoming information and old information <u>before</u> recognition has taken place. Secondly it is unparsimonious, though not logically impossible, to suppose that two memory systems exist in which the same semantic associations are stored quite independently of each other.

As well as evidence of semantic processing in short term memory, however, it was thought that evidence of actual semantic confusion in the short term, using recognition, should be demonstrated if possible.

Experiment 3 is a demonstration of semantic confusion in short term memory.

EXPERIMENT 3

METHOD

Subjects: The subjects were 50 undergraduate and research students at the University College of Swansea.
25 subjects were assigned to a control and the other 25 subjects were assigned to an experimental group, in a random manner.

Materials: The materials consisted of English words recorded on magnetic tape at the rate of 2 words per second, and English words read aloud by the experimenter from a list.

Design: If semantic confusion does occur in "STM", then the presentation of two semantically related words separated by about 6 seconds should result in errors of confusion with a third semantically related word in a test list, the whole being presented in an interval normally considered to lie in the range of "STM". To test this hypothesis, the experiment was designed in the following way:-

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Footnote: Since the experiment was conducted, an almost identical experiment was published by Underwood and Freund (1968) as were the experiments of Loess (1968) and Corman and Wickens (1968) referred to above. This present experiment can best be regarded, perhaps, as confirming the findings of these studies.

Two presentation lists were constructed from English words recorded at a rate of .5 seconds per word on magnetic tape. (See Table I)

TABLE I

Constitution of presentation and test lists.

Groups of words from which lists were constructed	Presentation Lists		Test List (T)
	Exptl. (EP)	Control (CP)	Exptl. & Control
20 frequent words	20	20	10 (O words)
20 infrequent words	20	20	10 (O words)
10 pairs semantically related words	20	-	-
10 words, each semantically but not acoustically related to one of the pairs	-	-	10 (R words)
20 words, each acoustically but not semantically related to the pairs.	-	20	-
5 frequent words	-	-	5 (NR words)
5 infrequent words	-	-	5 (NR words)

The experimental presentation (EP) list contained 60 words. Of these 20 consisted of 10 pairs of semantically related words (e.g., "slug" and "worm") scattered throughout the list in such a way that at least twelve words intervened between the members of a pair. Of the other 40 words, 20 had a frequency of 1 per million (low frequency) and 20 a frequency of 100 per million (high frequency), according to Thorndike and Lorge (1944). Subjects were instructed to listen to this tape passively and to make no attempt to learn it. Immediately after presentation, the test (T) list was read out by the experimenter, and the subjects were asked to give a rating for each word on the test list, after that word had been read out, according to how confident they were that the word had or had not occurred in the presentation list. The following scale was used:-

Y3	Y2	Y1	N1	N2	N3
Certain that word was old	Fairly certain that word was old.	Balance of probability that word was old	Balance of probability that word was new.	Fairly certain that word was new.	Certain that word was new.

For scoring purposes, the scale extended from 1 (N3) to 6 (Y3). The presentation of the T list took an average of 180 seconds.

The constitution of the T list is indicated in Table I.[/] Of the 40 words, 10 (R words) were semantically related to the pairs in the EP list, so as to form triads of words with related meanings (e.g. "snail" to go with "slug" and "worm"). The other 30 words consisted of 10 of the frequent and 10 of the infrequent words on the EP list (O words) and 10 words (5 frequent and 5 infrequent) which were new words (NR words), unrelated acoustically or semantically to the words on the EP list.

It was hypothesised that the R words would be given a higher rating than the NR words.

[/]Footnote: See Appendix II for the actual lists used.

Since it was possible that the R words would tend to receive a higher rating than the NR words due to factors other than semantic confusion (e.g. frequency) it was decided to run a control group of subjects who received a presentation (CP) list which did not contain pairs of semantically related words. The pairs of words in the EP list were replaced by words which were acoustically but not semantically similar to them, but were of approximately the same frequency. Thus "slum" and squirm" replaced "slug" and "worm". The test list and all other conditions were identical with those for the experimental group. If there was no semantic confusion effect in the experimental group, then the differences between the ratings of the R and NR words for the two groups should not have been significantly different.

RESULTS

Table II summarises the results for the three sets of words in the test list

TABLE II

Mean ratings of the words on the test list < not >

	Related words (R)	Unrelated words (NR)	Old words	R-NR
Experimental group	3.64	3.22	4.35	0.42 ($p < .005$)[1]
Control group	2.92	2.83	4.33	0.09 ($p \not< .05$)[1]
Difference (E-C)	0.72 ($p < .001$)[1]	0.39 ($p < .005$)[1]	0.02 ($p \not< .05$)[1]	0.33 ($p < .05$)[2]

1. Wilcoxon matched pairs signed ranks test
2. Large sample approximation to randomisation test. (Siegel 1956)

for both groups of subjects.

For the experimental group, R words were rated significantly higher ($p < .005$) than NR words. For the control group, this was not so ($p > .05$), indicating that the significant difference must have been due to some factor present in the EP list, but absent from the CP list.

That this difference is caused by semantic confusion is supported by the significant difference between the mean ratings of R words by the E and C groups ($p < .001$). That there was a significant difference between the ratings given to the NP words by the two groups of subjects ($p < .005$) indicates that some of the difference for the R words could have been caused by factors other than semantic confusion; in all probability, one of these would be the inevitable differences in the acoustic properties of the two tapes. However, the difference between the R words is significantly greater than that between the NR words ($p < .05$). This provides strong evidence for the general hypothesis. Table II also indicates that the old (O) words received the same ratings in the two conditions.

Discussion

It might be objected that the semantic confusion produced was a rapidly appearing LTM phenomenon. To argue this, however, is to admit that forgetting can take place rapidly in LTM, contrary to the view that LTM is a relatively stable memory system. This is because, as noted previously, confusion effects involve forgetting. As this experiment was conducted in a total time of not more than 220 seconds, forgetting in LTM, sufficient to have causedconfusion, must be supposed to have occurred.

The evidence so far produced indicates that semantic processing occurs in STM and that STM cannot be considered as being exclusively acoustic. The evidence of semantic processing comes from studies involving semantic facilitation, semantic interference (both PI and RI), and using both recognition and recall.

Baddeley and Dale (1966) do in fact admit some slight effects of semantic confusion in short term memory, but have tried to hold a dichotomous theory on the basis of quantitative differences between acoustic and semantic confusion, claiming that the former occurs in far greater quantity in "STM", the latter in far greater quantity in "LTM". Apart from the problems involved in comparing, quantitatively, two possibly unrelated processes, it is necessary, in order to postulate a dichotomous theory to show a dichotomy. At the very minimum, evidence of a dichotomous function over time is required in one or both processes of interference, actual quantitative differences between the two being irrelevant.

Whilst it is clear that there is adequate experimental evidence of semantic processing in STM it is perhaps surprising that such evidence is required in order to refute the hypothesis that STM does not employ semantic coding. That the words before one as one reads are almost instantaneously meaningful, indicates that they are almost instantaneously being semantically processed, but since many words are rapidly forgotten, these rapidly forgotten words must be considered to have been in STM only as noted in Chapter 4. Thus any attempt to claim that semantic processing of items is taking place on their entering LTM directly, is untenable. An experimental demonstration of rapid forgetting of ordinary English sentences is contained in a paper by Martin, Roberts and Collins (1968).

LONG TERM MEMORY

As with the importance of acoustic factors in STM experiments, there is no questioning of the importance of semantic factors in long term memory experiments. Thus McGeoch and McDonald (1931) and Johnson (1933) provide two early studies which show the effects of semantic factors in longer term forgetting, and more recently Baddeley (1966 b) has demonstrated the same. The critical question concerns the presence or absence of acoustic factors in "long term memory". Woodworth (1938) certainly considered that there was such evidence, and Conrad (1964) who is often misquoted in this connection, points to Woodworth's evidence as evidence of acoustic coding in LTM. In fact the 'evidence' provided by Woodworth, a list of words that had reportedly been confused, does not come up to modern day experimental requirements. In order to provide evidence of acoustic confusion in long term memory Gruneberg and Sykes (1969) devised an experiment in which a presentation list was followed, after a period of 20 - 25 minutes, by a test list containing words acoustically similar and words acoustically dissimilar to words on the presentation list. Subjects were asked to rate, on a six point scale, whether they thought the test list word was old or new. The finding that acoustically similar words were rated significantly higher than non related words was taken to indicate acoustic confusion in "LTM".

This experiment, was, in fact, also similar to one conducted by Underwood and Freund(1968) and like Underwoods and Freund's experiment, was open to the objection that despite the care taken, certain inelegancies were present in the structure of the lists. These inelegancies involved the possibility of semantic association factors, making it desirable to conduct a further experiment using redesigned lists. Experiment 4 is a report of this confirmatory experiment.[/]

EXPERIMENT 4

METHOD

Subjects

21 Undergraduate Students of University College Swansea.

DESIGN

The experimental design employed was basically the same as that of Gruneberg and Sykes (1969 b). A presentation list (Table 4) was read to S's at a speed of approximately 1 word every second, followed, 20-25 minutes later by a test list consisting of words acoustically related, words unrelated, and words identical to words on the presentation list (Table 5). Subjects were required to rate, on a six point scale whether they thought a test list word had or had not been, on the presentation list. On the test list, the words "fear" and "blood" always occurred in the first and eleventh positions respectively. The order of the other words was randomised for each group of subjects.

The present experiment differed from that of Gruneberg and Sykes in three respects only. 1) The presentation list consisted of 35 rather than 40 items. 2) The test list consisted of 9 rather than 10 acoustically related items, 9 rather than 10 unrelated items, and*

[/] The original experiment was also conducted with the explicit purpose of being used in this thesis.

* and 2 rather than 10 items identical to those on the presentation list. Finally the order of presentation of test list items was randomised in the present experiment.

TABLE 4

PRESENTATION LIST

(in order of presentation)

1.	Fear	13.	Judge	25.	North
2.	Sleep	14.	Hole	26.	Grass
3.	Note	15.	Camp	27.	Art
4.	Loss	16.	Storm	28.	Roof
5.	Wish	17.	Tie	29.	Crowd
6.	Week	18.	Cake	30.	Hand
7.	Lift	19.	Chair	31.	Train
8.	Mile	20.	Can	32.	God
9.	Cause	21.	Step	33.	Branch
10.	Shape	22.	Laugh	34.	Blood
11.	Ring	23.	Word	35.	Deal
12.	Drink	24.	Fit		

TABLE 5

TEST LIST

O	Fear	A	Lake	N	Fact
N	Dish	A	Bit	A	Work
N	Bridge	N	Soil	A	Fly
N	Wife	O	Blood	N	Queen
A	Coal	N	Town	A	Class
A	Shade	A	Hair	N	Height
N	News	N	Friend		

O = words on Presentation List.

A = words acoustically related to words on the presentation list.

N = New (unrelated) words.

Results

Using 21 S's, it was found that acoustically related items on the test list were confused to significantly greater extent with items on the presentation list, than were non-acoustically related test list items, ($P<0.002$ sign test), indicating acoustic confusion in LTM.

Discussion

Whilst the lists of words in Table 4 and 5 contain no items in the same semantic category as far as the authors are aware, there is clearly the possibility that associative factors play a part in any memory task involving high frequency items, and to this extent the claim of Gruneberg and Sykes (1969 b) that semantic relationship between items had been eliminated in their experiment was unjustified. However, the critical question is whether such associations can account for acoustically similar items being confused to a significantly greater extent than non-acoustically similar items. As there is no reason to suppose that in the present experiment, idiosyncratic semantic associations occur to a greater extent in acoustically related as opposed to acoustically unrelated items, differences in confusion rates between these two groups of items cannot reasonably be attributed to semantic factors. This experiment therefore, in confirming that of Gruneberg and Sykes (1969 b) gives clear empirical backing for the hypothesis that acoustic confusion occurs in LTM.

Despite the fact that the previous experiment indicates acoustic confusion in long term memory, it was thought desirable to conduct an experiment in which the possibility of semantic associations between items was minimised. It was also thought desirable to investigate the possibility of acoustic confusion in terms of hours rather than minutes, after presentation. The following experiment, conducted by three undergraduates, Stephen Colwill, Paul Winfraw and Robin Woods, under the supervision of the writer, was an attempt to carry out these aims.

EXPERIMENT 5

METHOD

Subjects

25 Undergraduate students of University College of Swansea, living in a hall of residence. Subjects were tested individually.

Materials

These consisted of a presentation list and a test list of nonsense CVC's. All but three of the CVC's were taken from Hilgard's Tables 8 and 9 "Tables of Associative Values" (Stevens 1951). The three other CVC's were added by the experimenters. Two Forth Instruments memory drums were used to present the lists.

DESIGN

If nonsense CVC Trigrams are confused with acoustically similar CVC's presented 10 - 12 hours earlier to a greater extent than are non-acoustically similar CVC's, then one has evidence of acoustic confusion in long term memory.

Nonsense CVC Trigrams were chosen for the experiment because, despite the possibility of semantic associations between the trigrams and real words, there is, almost by definition, only the remotest possibility of semantic associations between nonsense CVC's themselves. Hence any differences between acoustically related and acoustically unrelated items could not readily be accounted for in terms of semantic confusion effects between nonsense CVC's themselves. Furthermore, even if some idiosyncratic semantic associations do exist there is no reason to suppose they occur to a greater extent in acoustically related as opposed to acoustically unrelated items. Thus, differences between acoustically related and acoustically unrelated nonsense CVC's could not reasonably be attributed to semantic factors.

The presentation list (see Table 6) consisted of 20 CVC's with each vowel equally represented. Each item was typed 5 times along a single line e.g.

DAJ DAJ DAJ DAJ DAJ

The test list consisted of 10 "old" CVC's which occurred in the presentation list ('P' items), 10 CVC's acoustically related to CVC's on the presentation list ('A' items) e.g. MEF for MEV, and 10 "new" CVC's acoustically unrelated to CVC's on the presentation list ('N' items), each item being presented only once (see Table 7).

The experimental procedure was as follows:-
Each S was seated before a memory drum and told to concentrate on reading silently each "unusual" word as it appeared. Each CVC was exposed for a total of 4 seconds, thus the total initial exposure of the presentation list was 80 seconds. There was then a pause of 4 seconds before the presentation list was again presented in exactly the same manner. Thus the total presentation time was 164 seconds.

All S's were given the presentation list between 21.05B.S.T. and 23.15 B.S.T., and following presentations subjects were instructed not to write down any of the words, not to discuss the experiment with others, and to return the following morning.

All subjects were tested the following day between the hours of 08.40 and 10.05 B.S.T. The mean interval between presentation and test list exposure was 10.88 hours, with a range from 10 hours to 12 hours 10 minutes. The test list was presented at the same speed as the presentation list i.e. one item every 4 seconds; S's were provided with a sheet of lined paper and were instructed to work down a column, entering a tick for an item which they recognised as having occurred previously on the presentation list, and a cross for any item not so recognised.

The prediction was that 'A' items would receive more false positive responses than 'N' items.

RESULTS

The number of false positive responses to the items on the test list which were acoustically related to items on the presentation list, ('A' items) was significantly greater than the number of false positive responses to CVC's on the test list unrelated to CVC's on the presentation list ('N' items) ($P < 0.001$ Wilcoxon's matched-pairs signed-ranks test). The exclusion of the three CVC trigrams added by the experimenters, from statistical calculations made no difference to the significance of the results.

DISCUSSION

It might be objected that with trigrams it is impossible to ensure that the acoustically unrelated ('N' items) on the test list are not to some extent acoustically related to presentation list items, particularly as all the vowels were used in the presentation list. This may be so but the effect of having 'N' items to some extent acoustically related to presentation list items would be to reduce differences between 'N' item and 'A' item false positive scores and hence work

Table 6. Presentation List

20 CVC's (in order of presentation

(1) DAJ	YAG
YEM	MIZ
KIV	ZAF
TUZ	WOV
BIP	FUF
MEV	VOJ
ZOL	FEP
GIC	JUC
VUT	YOD
BEJ	(20) KAX

Table 7. Test List

30 CVC's

(1) ZAV a	JEX n	FEP p
YIN n	YEM p	WOF a
TUZ p	SUF a	JUC p
MEF a	BIP p	TEB n
YAG p	LIJ n	MIZ p
HIF n	ZOL p	VUP a
DAJ p	KAS a	REL n
KIB a	JOM n	PEJ a
WUX n	GIP a	GUK n
TOJ a	JAT n	(30) YOD p

'p' = syllable on Presentation List

'a' = syllable acoustically related to Pres. List syllables.

'n' = syllables acoustically unrelated to Pres. List syllables.

against the hypothesis.

Again it may be objected that the results are due to visual similarity factors, in that the acoustically similar items are also visually similar. It is certainly a possibility but one which is extremely awkward for a dichotomous theory. Dichotomous theorists such as Adams (1967) maintain that visual material is encoded in acoustic form in STM before transfer to a long term memory, which employs a semantic coding. It therefore hardly seems possible for a dichotomous theorist to argue that the present results can be accounted for in terms of visual confusion and coding effects in long term memory.

These results then, confirm the earlier findings of Gruneberg and Sykes (1969 b) that acoustic confusion occurs in LTM, and indeed extend the findings by showing that they occur some 10 - 12 hours after presentation.

The results of these two experiments, together with a recent experiment of Bruce and Crawley (1970) showing "long term" acoustic confusion using a recall, rather than recognition technique, and indeed an earlier experiment by Brown and McNeil (1966) indicates quite clearly the presence of acoustic confusion in LTM. (Brown and McNiel found that when subjects guessed the word for which a meaning was supplied, an acoustically similar, but incorrect word was oftan given). As with evidence of semantic processing, however, in STM experiments, the evidence for acoustic processes at work in LTM hardly needs experimental support. That any subject can on request, produce a list of words acoustically similar to any specified word, indicates that the organisation of long term memory involves acoustic coding.

Apart from the empirical evidence for semantic and acoustic coding in both STM and LTM, there are such problems in holding that a dichotomous theory of memory can be based on differing coding systems, that it is surprising that the hypothesis has ever been seriously entertained. If short term memory uses acoustic coding only, and long term memory semantic coding only, then transfer from short term memory to long term is impossible without the intervention of a mechanism which translates auditory coding into semantic coding. Such a mechanism would have to be as large as short and long term memory stores combined, which makes the postulation of a short and long term memory separate from such a compiler unparsimonious. Such a compiler entails LTM being able to use an auditory coding system at any time, and makes the distinction between STM and LTM, on the basis of acoustic coding being an STM characteristic only, untenable.

A further difficulty in holding the hypothesis that only STM is subject to acoustic confusion concerns the empirical evidence provided by Baddeley (1966 a) that long term learning of acoustically confusing material can take place, and at approximately the same rate as non-confusable material. It is generally held by dichotomous theorists that material in short term memory is either transferred to long term memory or lost. As acoustic confusion is confined to STM, acoustically confused material must, according to the dichotomous position, be lost - a finding, as pointed out above, not borne out by empirical evidence.

General Considerations

Even were evidence of acoustic confusion being confined to STM empirically justified, it is not possible to draw the conclusion that one can make a general statement about the nature of two memory systems, otherwise it is difficult to see how the deaf or indeed anyone can learn verbal material. As noted earlier, Ross (1969) found nc difference in memory span between deaf and non-deaf subjects, and Conrad and Rush (1965) found that the congenitally deaf do not make errors of acoustic confusion in STM where non-deaf subjects do.

Again more than making untenable a dichotomy on the basis of differing interference effects, the evidence for semantic processing in STM has serious implications for any dichotomous theory of memory. For semantic processing to occur at all, the items processed must functionally have entered LTM, in that meaningfulness or even non-sensory associativity is a function of the previous history of the individual. Thus any theoretical interpretation of memory in terms of two "boxes", a short term and a long term "box" is untenable.

Norman (1968) has recently attacked a "box" dichotomous theory on similar grounds to those above, although he appears unwilling to allow that semantic similarity can effect retention in Primary memory and maintains a dichotomous theory on the grounds of such operational distinctions, as the exclusive presence of acoustic similarity factors in Primary memory and semantic similarity factors in Secondary memory. Apart from the empirical evidence against such operational distinctions, it is difficult to reconcile these operational distinctions with Norman's view of Primary and Secondary memory as having such "direct" and complete intercommunication that a formal distinction between the two is difficult to make". If such intercommunication is possible, it must be because both systems use the same coding system, otherwise such communication would not be possible. Furthermore, if as Norman claims, the items in Primary memory are affected by acoustical similarity are those "which are to be retained", it follows that one cannot account for differences between forgetting rates for acoustically

similar and acoustically dissimilar material in terms of acoustic interference, (Baddeley 1966) as the "extra" items forgotten in the acoustically similar groups must according to Norman's formulation, be forgotten for reasons other than their acoustic features.
It must be admitted that the question of whether acoustic and semantic coding are confined to STM and LTM respectively is now something of a non issue; a diversion in the study of memory which will be forgotten in the course of time, except perhaps to exemplify the way in which psychological explanation and common sense parted company, and how common sense won. Thus Baddeley (Baddeley and Warrington (1970) now concedes that common sense dictates the postulation of acoustic coding in LTM - as well as empirical data, and Wickelgren (1969 a) even predicts that acoustic confusion in LTM will be shown in due course. It is to be hoped, however, that the papers of Gruneberg and Sykes (1969 a, b) and Gruneberg et al (1970) will do something to put beyond resurrection this particular issue.

Summary

This chapter, then was concerned to show that evidence to support a dichotomous theory of memory cannot come from a demonstration of dichotomous coding systems in STM and LTM. Empirically such a distinction is unjustified in that experimental evidence was produced of acoustic confusion in LTM and of semantic confusion in STM. In addition to the experimental evidence of the present writer, a large number of studies were quoted showing evidence of semantic processing in STM, and the evidence of Woodworth (1938) was tentatively suggested as evidence for acoustic coding in LTM. It was however stressed that the need for experimental evidence to support the hypothesis that acoustic coding occurred in LTM and semantic coding occurred in STM was unnecessary; words are almost instantaneously meaningful to almost all 'S's, yet many are rapidly forgotten, indicating semantic processing in STM. Again almost all 'S's can produce a list of words which sound similar to any specified word, indicating acoustic coding in LTM. This does not mean of course that it is impossible to interpret the data in dichotomous terms, were a dichotomy provable on other grounds. What is being claimed is that a distinction between STM and LTM cannot be established on the basis of differing coding systems as between STM and LTM.

Apart from empirical objections, there is a major logical objection to dichotomising on the basis of differing coding systems being employed by the two purported systems. It would not be possible to transfer material from one system to another unless a common coding system were used and stored in LTM.

Finally, two points of importance stem from the demonstration of semantic processing in STM using recognition. Firstly it is difficult to dichotomise between recognition and recall in the face of such evidence; secondly, it is impossible to hold any dichotomous theory which looks at memory in terms of two 'boxes' - a short and a long term box - whatever evidence is produced for any other kind of dichotomous theory.

CHAPTER 10

THE SERIAL POSITION CURVE

The Nature of the Evidence

In recent years the shape of the serial position curve has taken an important place in the theoretical context of the number and nature of memory systems. This is particularly true of free recall experiments, where alterations in the shape of the serial position curve as a result of experimental manipulation have been used by many writers as evidence of a dichotomous theory of memory. Baddeley and Warrington (1970) regard this type of evidence as one of the three main lines of evidence for a dichotomy. Murdock (1967) discusses it when looking at characteristics of short term memory. Glanzer and his co-workers (Glanzer and Cunitz (1966)), Glanzer (1969), Glanzer and Meinzer (1967), and Glanzer et al (1969) base their assumptions of a dichotomy between short and long term memory on the different reactivity of the serial position curve to various variables. Waugh and Norman (1965) use the shape of the serial position curve to distinguish operationally between short and long term memory and Tulving (1968) regards the evidence as providing - P 12 - "strong support for the hypothesis that at least two different recall mechanisms are involved in free recall." Peterson (1966 b) on the basis of paired associate studies, also supports a dichotomy on the basis of the differential reactivity of the early and later part of the forgetting curve to such variables as repetition. As opposed to these views, Adams (1967) considers that free recall lacks the requirement for preservation of order so that there are ample opportunities for material to enter LTM. A considera-

-tion of the implications of free recall studies for a dichotomous theory is notably absent from his book. Yet the importance placed on the serial position curve by many dichotomous theorists requires an examination of the data.

There is, in fact, little dispute that various variables alter the shape of the serial position curve. Murdock (1962) found that the list length and rate of presentation of items did not affect the recency part of the serial position curve, but did affect the primacy and middle parts of the curve. Glanzer and Cunitz (1966) also found that rate of presentation affected only the earlier part of the curve, and in a second experiment noted that a delay, filled by interpolated activity for about 30 seconds, resulted in a loss of items at the end of the serial position curve, but not for earlier items, a finding confirmed by Postman and Phillip (1965). Glanzer and Meinzer (1967) showed that overt repetition of items between presentation,depressed the earlier, but not the later part of the serial position curve. Craik (1968) showed the effects of acoustic similarity on the recency part of the curve. Kintsch and Buschke (1969) also succeeded in showing the effects of acoustic similarity on the recency part of the curve, and in addition showed the effects of semantic similarity on the earlier part. Glanzer et al (1969) succeeded in showing that the nature of the interpolated activity following the presentation of items did not, in their experiment, affect the rate of forgetting of the terminal items, but that the number of items alone was critical and did affect the recency part of the curve. Craik (1970) found that with long interpolated activity the end part of the serial position curve fell past the level to which the rest of the curve (asymptote) had fallen, and claimed that this evidence, too, indicated two memory systems. Finally Raymond (1969) confirmed many of the findings in showing that presentation rate, nature of stimuli, and frequency, for instance, affected the first part of the curve, but that delay affected only the recency part of the curve.

A Single System Theory Interpretation

In order to understand the reason why these lines of evidence do not establish a dichotomous theory of memory, it is necessary to recall the argument put forward in Chapter 4 to show that lines of evidence, based on the serial position curve, are based on the assumption that rapid forgetting distinguishes between short and long term memory. The argument put forward in Chapter 4 was that, as Postman and Keppel (1968) noted, the later in a sequence an item was presented, the closer it was to the retention test. Furthermore, as the most recently presented items are the first recalled, this is accentuated, and the serial position curve can thus be viewed as a forgetting curve of sorts. The recency part of the curve represents probability of recall for items newly presented, as one progresses "back " from the recency part of the curve, so items are relatively longer in store up to the point of the retention test. The decline in the recency effect with time therefore, merely is an indication of the early part of the forgetting curve, which also, unlike the serial position curve, reaches an asymptote. It is true that the primacy part of the serial position curve is missing from the forgetting curve, but items retained from the early part of the serial position curve merely serve to raise the asymptotic level of the forgetting curve. The recency part of the curve in other words, indicates the time course of rapid forgetting, and indeed there is no reason to suppose that this supposition is unacceptable to those holding a dichotomy.* They would argue that this rapid decrement in recall probability is affected by factors other than those affecting recall probability in long term memory and that this indicates two underlying memory mechanisms. The main underlying assumption is that those factors which cause forgetting in one system are different from those which cause forgetting in the other.

In holding a single system theory one also views the recency part of the serial position curve as indicating rapid forgetting of recently presented items. It is the interpretation of the earlier part of the curve which differs. Dichotomous theorists view this as basically output from a different memory system, those holding a single system theory regarding the serial position curve as showing the rate of forgetting (the slope of the recency part of the curve) and the extent of rapid forgetting (the point at which the curve becomes asymptotic). In other words, it is suggested that rather than acting differentially on two different storage mechanisms, each variable considered above, acts on incoming information either to affect the rate or the extent of rapid forgetting.

There still, of course, remains the problem for a single system theorist, of why some variables affect the rate, but not the extent of rapid forgetting, and vice versa. Why in other words, are the rate and extent of rapid forgetting independent? It may be a difficult question

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* Footnote: Peterson (1966 b) presents his data in the form of a forgetting curve rather than a serial position.

to answer, but it does appear to be one to which a dichotomous theory provides not obvious solution. The various lines of evidence are now considered in order to examine their possible interpretation in single system theory terms.

List Length

The first line of evidence to be considered is that whilst list length does affect recall of items from input positions preceding the 'recency' range, it does not affect the recency part of the curve. (Murdock 1962). This is a case in which one is required to ask why increasing the length of a list should result in increasing the extent of rapid forgetting, but not the rate, i.e. the greater the list length, the lower is the asymptote.

It is not unreasonable to suggest that either an autonomous trace decay or an interference model of forgetting can handle the fact of the lower asymptote, by assuming the greater the amount of material, the greater will be interference, whether caused by, or the cause of, forgetting. Indeed an increase of interference can be expected with greater list length, in that there is a greater interpolation of material between presentation and recall for more of the items. In order to account for a failure to affect rate of decay, however, it must be assumed that the greater interference produced as a result of increasing the number of items, takes a short time to operate - whether this time is due to neurological degeneration or subsequent experiential factors. Peterson (1966 c) in noting that the most recently presented items have not had time to go through their period of steepest decline is making the same point. This, as was noted earlier, is because the most recently presented items are the earliest recalled (e.g. Deese and Kaufman 1957).

(In theory, therefore, an immediate free recall task should involve no delay between presentation of the last item and its recall).

Rate of Presentation

Murdock (1962) Glanzer and Cunitz (1966) and Raymond (1969) have all found that differences in rate of presentation of data affects the earlier part of the serial position curve, but has no effect on the recency part of the curve. Again the question is posed as to why decreasing the rate of presentation of items should decrease the extent of rapid forgetting, but not the rate.

There is again little problem in explaining why rate of presentation should affect the extent of rapid forgetting. The greater the opportunity for rehearsal, the greater is retention, and as rate of presentation increases, so do opportunities for rehearsal decrease. Thus with slower rates of presentation the extent of forgetting is reduced, i.e. the forgetting curve is prevented from falling below the level to which it would otherwise fall.

In noting that rehearsal does not alter the rate of decay one is merely restating Brown's (1958) comment that rehearsal serves merely to prevent decay. It must again be assumed that those factors which prevent decay or interference do not operate immediately but require a period of time. It is in fact common experience that rehearsal does not necessarily prevent rapid forgetting.

It must be presumed thatthose holding a dichotomy would interpret the increase in level of the early part of the serial position curve with increased rehearsal opportunities, as evidence that increasing rehearsal in short term memory enables better transfer to long term memory to take place.

Interpolation of Activity between Presentation and Recall

The next line of evidence put forward, by Glanzer and Cunitz (1966) and Postman and Phillip (1965) is that interpolation of a task between presentation and recall reduces the recency part of the curve to the level of the asymptote, and Craik (1970) has shown that large amounts of interpolated activity in fact reduce the recency part of the curve still further, so that it is below the level of the asymptote. On the other hand Peterson (1966 c) shows that for paired associates, there is a recovery of the last items as a result of interpolation of activity, yet he too interprets the evidence in favour of a dichotomous theory (on the grounds of switching from one retrieval mechanism to a more efficient long term mechanism).

Again one comes back to Peterson's (1966 c) point that the last few items presented when immediate recall is required in a free recall experiment, have not had time to go through their period of steepest decline, (the steepest decline being early in the forgetting curve) whereas items presented earlier in the list have. Therefore, interpolating activity between presentation and recall will give items the opportunity to go through their period of steepest decline. The evidence on the effect of interpolation of activity clearly does not explain the reason for the steep decline; it merely describes what is already known, that forgetting is sometimes rapid. Craik's (1970) finding that the recency part of the curve falls below the asymptote is not difficult to account for if one uses his own arguments for the phenomenon. He argues effectively that since the last items in a list remain in a rehearsal buffer for less time than other items, there will be less opportunity for rehearsal for the terminal items, and that therefore there will be less chance to maintain processes which serve to prevent decay. Even Adams (1967) however, notes that the effects of rehearsal can be accounted for by both theories, so that if there is less rehearsal time available to the last items, both a single and a dichotomous theory would predict a fall in the recency part of the curve below the level of the asymptote.

<u>The Effects of Repetition</u>

Craik goes on to claim that the strength of registration in LTM depends on the length of an item's stay in the buffer. The evidence of Glanzer and Meinzer (1967) flatly contradicts this assertion. Their experimental evidence consisted of two conditions, a control condition which was a normal free recall experiment, where there was no interpolation of activity between the presentation of each item, and an experimental condition, in which each item was repeated rather than allowing free activity. The result was that whereas there was no effect on the recency part of the curve, the earlier part of the curve was depressed by this repetition. Yet on Craik's argument, and on the model of Atkinson and Shiffrin (1968), one would expect that repetition, by keeping each item in short term store, at least as long as any other strategy, is likely to increase the strength of registration in LTM.*

As was noted in Chapter 7, there is a growing body of evidence which supports Glanzer and Meinzer's findings that repetition does not

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* <u>Footnote:</u> Tulving and Madigen (1970) note that Atkinson and Shiffrin (1968) produce the same sort of result, and consider that far from supporting Atkinson and Shiffrin's dichotomous model, it is a severe embarrasment, as it is to all dichotomous theories.

of itself lead to permanent storage. (e.g. Eagle (1967) found that those who associated in a free recall situation performed better than those who repeated items to themselves, and Dalrymple and Alford (1967) similarly found no advantage in mere repetition). As Neisser (1967) and others suggest, there is more to rehearsal, therefore, than mere repetition, and more to preventing decay than repetition. Neisser's suggestion that organisational factors are critical seems reasonable in view of the evidence. The evidence of Glanzer and Meinzer (1967) therefore, is somewhat more uncomfortable for a dichotomous theory than for a single system theory. At least a single system theory makes no claim that the longer an item "resides" in "STM" the greater is its strength in LTM.

The Nature of Rapid Forgetting

Glanzer et al (1969) use the serial position curve to try to clarify the cause of rapid forgetting. They completely reject the earlier view of Glanzer and Cunitz (1966) that time per se causes forgetting, and conduct an experiment in which they show that the number of items interpolated between presentation and test is the critical factor, a finding earlier reported by Waugh and Norman (1965). They further reject the role of similarity in rapid forgetting, finding as they do that formal similarity of interpolated activity to the original items has no measurable effect on rapid forgetting. This finding is of course, a restatement of the position of Broadbent (1963). As noted in Chapter 5, this is contradicted by the findings of Wickelgren (1965 a, b) on acoustic similarity affecting short term memory, and Corman and Wickens (1968), who found semantic similarity affected short term memory.

Glanzer et al reject the experimental evidence of Wickelgren as showing similarity effects, on the grounds that the interference effects produced might be operating in LTM, as might any interference effects in Peterson and Peterson (1959) paradigms. As was noted in Chapter 6, however, it is impossible to claim that one can have rapid forgetting from LTM i.e. within about 30 seconds, without compromising the criterion for distinguishing long from short term memory. Either long term memory is a stable system, in which case once in store, items are relatively free from loss, or alternatively items in LTS are subject to rapid loss, in which case one cannot claim that any forgotten material is not lost from LTS.

The argument of Glanzer et al, can in fact be turned round. If there is a possibility of the experiments of Wickelgren indicating loss from LTS, it must be possible that retro-active factors can cause a depression in recall of items from earlier parts of the serial position curve, within a short period of presentation of such items. Thus, all sections of the serial position curve being susceptible to retro-action causing rapid forgetting, one cannot dichotomise between STM and LTM on the basis of experiments on the shape of the serial position curve.

Even if one were to reject the evidence of Wickelgren (1965a) and Corman and Wickens (1968) as showing associative interference effects in the short term, the evidence of Kintsch and Buschke (1969) and Craik (1968) cannot be easily dismissed, because they used the criterion of Glanzer in deciding whether acoustic confusion was or was not confined to short term memory. In other words, they showed that the recency part of the serial position curve was decremented by the presence of acoustically similar material. Furthermore, the evidence of Baddeley (1966 b) showing acoustic confusion after presentation of 5 items can hardly be considered a long term memory experiment!

Acoustic and Semantic Similarity

The evidence of Kintsch and Buschke is perhaps the most difficult for a single system theorist to account for. Yet the fact that the conclusions based on the shape of the serial position curve for this experiment, have no generality, is fatal for the dichotomous theory position based on the serial position curve. The difficulty in explaining the data, as far as a single system theorist is concerned, arises from the fact that acoustic similarity affected the recency part of the curve - the rate of forgetting, but not the asymptotic level - the extent of forgetting. Possibly acoustic interference attacks only those items unduly susceptible to forgetting. For present purposes it does not, in fact, matter. Bruce and Crawley (1970) have shown that whatever the difficulties for a single system theory, the evidence is impossible for dichotomous theorists. They found that massed presentation of acoustically similar items did affect the earlier part of the serial position curve, whereas spaced similarity (the Kintsch and Buschke experiment) did not. It cannot be claimed therefore that failure to show a difference in the action of a variable on one part of the curve as compared to another establishes a dichotomy. It merely indicates that the effect is too small to measure by means of the technique employed. Even without the experiment of Bruce and Crawley (1970) however, the generality of the findings of Kintsch and Buschke, and of Craik, were suspect, as the evidence of Underwood and Freund (1968), Gruneberg and Sykes (1969) and Gruneberg et al (1970) have shown. As was noted in Chapter 9, it is logically impossible to dichotomise on the basis of acoustic coding being confined to short term memory only.

Amnesic and Non-amnesic subjects

A further finding, based on the serial position curve, which is an embarrassment to dichotomous theorists, is reported by Baddeley and Warrington (1970). They show that whereas the performance of amnesics on the early and middle section of the curve is inferior to non amnesics, there is no difference between the two groups on the recency section of the curve. Whilst Baddeley and Warrington interpret this data to indicate that amnesics have an unimpaired short term memory, the results are an acute embarrassment to those many dichotomous theorists, e.g. Waugh and Norman (1965) who postulate that short and long term memory can exist simultaneously. If this is the case, and if the recency part of the curve represents output from both short and long term memory, as is claimed, then the amnesics should perform less well than non amnesics on the recency part of the curve. This is because they have, it is claimed, no long term memory component to supplement output from short term memory, for the recency part of the curve.

Conclusion

It has to be admitted that the account given by the writer, of the interpretation of the various serial position curves, in terms of a single system theory, lacks conviction at times, yet as the above paragraph indicates, so does the alternative view. Whilst therefore it is allowed that the serial position curve can perhaps be interpreted in terms of a dichotomous theory, an interpretation in terms of a single system theory is equally possible. The evidence from the serial position curve however, merely reposes many of the problems found by other experimental means, e.g. why rapid acoustic confusion? why the difficulty in showing similarity effects over the short term? why does rehearsal improve retention? why does mere repetition not help ? and of course the main question, why rapid forgetting? It does not answer these questions beyond stating a possible hypothesis i.e. two memory systems.

Summary

This chapter has reviewed the evidence for a dichotomous theory of memory based on the differential reactivity of the serial position curve to a number of variables. These variables included repetition, rate of presentation, list length and similarity. It was noted that the problem posed for a single system theorist is why do some variables affect the extent, but not the rate of rapid forgetting. Whilst it was relatively easy to account for the differences due to extent of rapid forgetting, it was more problematic to account for the reason that rate was unaffected. It was assumed that those factors which cause forgetting require time to operate. An analogy might be two different sizes of wave, moving at the same speed.

This explanation of the serial position curve contrasts with that of the dichotomist theorist who claims that the differential effects of variables indicate two separate memory systems. Yet many of the findings are merely restatements of what is already known, and can be regarded in one form or another, as posing the question as to the cause of rapid forgetting, rather than answering it.

At least three of the findings reported, that of Glanzer and Meinzer (1967) and Kintsch and Buschke (1969) and Baddeley and Warrington (1970) are embarassments to a dichotomous theory, the first because a dichotomous theorist should hypothesise contrary results, the second because its generality is questionable on the basis of the experiment of Bruce and Crawley (1970) and others, and opens up the possibility that all failures to find differences in the shape of certain parts of the serial position curve, as a consequence of an experimental variable, may be due to the variable being too weak an effect to measure, not due to its absence. Finally the experimental evidence of Baddeley and Warrington (1970) indicates that it is not possible to interpret the recency portion of the serial position curve in terms of output from both short and long term memory.

CHAPTER 11

PHYSIOLOGICAL EVIDENCE AND A DICHOTOMOUS THEORY OF MEMORY

Perhaps the first possibility which should be considered in a chapter of this nature is the possibility that physiological evidence has no direct relevance to the question of whether, at a psychological level, one can use explanations in terms of one memory system or two. There are two reasons for this. The first, pointed out by McGeoch (1942) and more recently by Reynolds (1965) for instance, is that evidence which is obtained on the basis of physiological abnormality is not necessarily of relevance to the psychology of normal behaviour, because insult is an irruption into the normal process of memory and cannot be used to draw inferences about normal functioning.

Within the context of memory, therefore, all those many papers showing evidence of a dichotomy between short and long term memory on the basis of illness (Korsakoff's syndrome) Hippocampal lesion, introduction of drugs, electro-convulsive shock and so on, are subject to this objection: they do not necessarily tell what normal functioning involves, the effects may be the direct result of the abnormality.

The second query of relevance concerns evidence of a more molecular level. Can knowledge of physiological processes over time, per se, help in the solving of the problem? Here, many psychologists, even those holding a dichotomous theory e.g. Shiffrin and Atkinson (1969), Norman (1969), are agreed that the answer is no. Shiffrin and Atkinson, for instance, do not mind what structural form short term memory takes, whether it is in a separate part of the brain from LTM or whether it is just the activity phase suggested by Hebb (1949). It does not matter to the psychologist, as such, how information is stored, whether in tape recorders, plastic discs, neurons or whatever, provided a transformation from one form of storage to another is of a one to one nature, or that losses from any form of storage are due to the same factors as in any other storage form. Thus if experiential factors e.g. acoustic similarity, cause a memory loss in one physiological state, and also a loss in the other physiological state, then the actual physiological states are irrelevant to a consideration of the problem. Only if a physiological state is of such a nature that it causes information loss for reasons other than the cause of information loss in another physiological state, can one regard the consideration of physiological evidence relevant. After all, in any chemical reaction in the brain, there are probably millions of transformations, yet it is not parsimonious to regard these as millions of memory systems, from the psychologist's point of view.

For these reasons, then, a detailed account of physiological changes consequent upon learning, will not be considered in this chapter. Only those lines of evidence which suggest that underlying physiological states may involve different forgetting phenomena will be considered. There are, in fact, three major lines of physiological evidence upon which claims of a dichotomy have been based: the effects of electro-convulsive shock, the effects of drugs, and the effects of physiological lesions, on behaviour. These are now considered in turn.

Electro-convulsive shock

Weiskrantz (1966, 1967) has suggested that the memory changes which result from electro-convulsive shock (ECS) are grounds for holding that short and long term memory are dichotomous, although he concedes that it is impossible to prove that retention impairment is not solely a function of failure to retrieve.

Behaviourally the effects of ECS involve the production of retrograde amnesia such that events recently learned are most susceptible to forgetting. Such amnesic effects can, however, cover a span of several weeks, as a study by Bickford et al (quoted Weiskrantz) shows. Typically there is a shrinkage of memory loss with the older memories returning first but not necessarily in chronological order. Thus "Islands of memory" are often reported.

That ECS (and indeed other mechanical shock) can have effects extending over long periods of time is indicative that such shock is affecting "long" as well as "short" term memory, as Weiskrantz notes. Thus the fact of retroactive interference as such does not indicate a dichotomy. Yet there are features of ECS which have led Weiskrantz to postulate a dichotomy. These features centre round studies which indicate the irreversable nature of ECS for material learned up to about 5 seconds before shock e.g. Chorover and Schiller (1965). On this basis Weiskrantz argues that after a period of about 5 seconds, the trace is irreversable and shock serves to increase the amount of interfering noise in the system. As this subsides, so retrieval again becomes possible. On the other hand, the irretrievability of recently taken in information, even after a long lapse of time, can be taken to indicate an irreversible loss of information.

Various experiments make such an interpretation equivocal. Jarvick and Kopf (1967) showed that increasing the level of shock increased amnesia. Earlier Weissman (1963) had shown no amnesic effect for sub convulsive shock and following on this Pag no et al (1969) showed that a complete recovery of memory was possible following amnesia, provided that the intensity of the shock was not too great, a finding similar to that of Zinkin and Miller (1967). With greater intensity amnesia did appear to be permanent. This is an extremely important finding, because it tends to indicate that, as for the longer term forgetting produced by ECS, the underlying memory trace is laid down but not available. Whether this is the correct interpretation or not, it seems reasonable to claim that the data does not compel an acceptance of a two stage model.

Protein Synthesis Inhibitors

The second line of physiological evidence put forward - the effect of protein synthesis inhibitors on memory - has been reviewed by Deutsch (1969). The type of evidence which is claimed to support a dichotomous theory is of the type by Flexner et al (1967), in which the injection of Puromycin (a protein synthesis inhibitor) interferes with memory. Thus, trained mice injected with puromycin 1 - 60 days after training are retested 3 - 4 days after the injection. A memory defect is inferred from saving on learning scores. As Deutsch, not unreasonably points out, if relearning is impaired, this would give a score which could indicate a non existent memory defect. Again the time interval, 1 day after training, is too long to have implications for a dichotomous theory of memory, in which minutes rather than hours are assumed to indicate long term memory.

Finally an experiment by Flexner and Flexner (1967) indicates that their experiments are not concerned with a dichotomous theory of memory. Injections of saline solution after puromycin treatment abolished puromycin-induced amnesia; the saline not being injected until at least 28 hours after training.

The experiments of Barondes and Cohen (1966) however, go some way towards meeting the time criteria, in that they injected puromycin immediately after learning, rather than 1 - 60 days after training, as in the Flexner experiments. They found that memory loss did develop within a relatively short period of time (3 hours), so that it is possible that puromycin can affect memory formation. Yet again however, saline injected within 30 hours of puromycin (Flexner and Flexner) resulted in almost unimpaired memory. Animals other than rats or mice have been examined after injection with protein synthesis inhibitors. Agranoff and Klinger (1964) found that after training on shock avoidance immediate injection of puromycin in goldfish caused forgetting after 3 days. Apart from the time discrepancy between these results and those of general experimental psychology, Deutsch points out that such results may be due to diminution of fear, rather than any memory effects.

An experiment by Barondes and Cohen (1967) is extremely awkward for those who would interpret the evidence in terms of protein synthesis inhibition disrupting a transfer from short to long term memory. They injected a protein synthesis inhibitor, cyclohexamide, five hours before training, in such quantities that protein synthesis would be inhibited for at least eight hours, yet retention was not impaired at 3, 13 or 70 hours after training. They conclude that protein synthesis is not required either for organisation or consolidation.

These workers (Cohen et al 1966) had previously found that puromycin, but not cyclohexamide induces abnormal electrical activity in the brain. It is not unreasonable to conclude that puromycin involves active interference with memory response.

On the basis of experiments on protein synthesis inhibitors Deutsch remarks P 89 "the fact that no one has devised an experiment capable of deciding between a single process and a multi-process theory." On P 91 he summarises the work on the relevance of protein synthesis inhibitors to memory as follows. "It must be shown that they affect memory at all, let alone whether they affect retrieval or storage." It seems reasonable to conclude at this stage of our knowledge that a dichotomous theory of memory on the basis of evidence from protein synthesis inhibitors has not yet been established. (It might be added that the time course of forgetting produced by cholinergic drugs raises similar objections to those above. Deutsch (1966) showed that whilst memory was unimpaired for 3 days following injection of such a drug, it did affect memory 14 days after training - a time course too long to be intepretable in terms of a dichotomous theory of memory.)

Brain Lesions and Memory

Perhaps the most important physiological evidence upon which a dichotomy is based, rests on the nature of memory disorder following temporal lobe and hippocampal lesion. A great deal of evidence is available which suggests that subjects with such lesions have unimpaired "short term memory", and unimpaired "long term memory", but the ability to learn new material is very much impaired.

Many psychologists rely heavily on this type of evidence in postulating a dichotomous theory of memory. Atkinson and Shiffrin (1968) P 97 describe the effects of hippocampal lesions as "perhaps the single most convincing demonstration of a dichotomy of memory systems." They go on to quote a section from Milner (1966) describing the effects of lesions in the hippocampal region, and note its relationship to Korsakoff's syndrome, which is also associated with hippocampal lesions (Barbizet 1963). Baddeley and Warrington (1970) advance temporal lobe lesion effects as one of the three major lines of evidence for a dichotomy. Adams (1967) also advances this type of evidence in favour of a dichotomy, and Wickelgren (1968) considers evidence of this sort as strongly indicative of a dichotomy.

Descriptions of the defects are well documented e.g. Milner (1966), (1968), Talland (1968) Barbizet (1963) and others. The defects have of course been known in psychology for a considerable time. The effects of hippocampal lesions were shown by Jabosen (1936) and Korsakoff's syndrome is documented in the last century (See Barbizet). Clearly this evidence presents a problem for those wishing to hold a single system theory. As the evidence to be reviewed presently shows, however, there are also problems of interpretation for a dichotomous theory.

The interpretation normally put forward of the defect is in terms of a breakdown in the ability to store new information in long term memory i.e. transfer from short to long term memory. Indeed only this interpretation is possible for a dichotomous theorist. If it is claimed that the forgetting is due to an accentuation of forgetting factors in STM, this is the interpretation that a unitary theorist would give i.e. in terms of an accentuation of those factors which universally cause forgetting. If an interpretation is made in terms of items entering LTM and being rapidly forgotten in that system, then, as has been pointed out in Chapter 4, the criterion for distinguishing between short and long term memory collapses, because long term memory must be regarded as a relatively stable memory system. How can one be sure that all forgetting is not due to items entering LTM and being lost by reason of universal forgetting factors?

Yet despite the claims made, the evidence is not unequivocal.

Douglas (1967) quotes a number of studies showing normal learning rates for rats with hippocampal lesions, on simultaneous black-white discrimination, on stimuli differing in size, etc., and concludes that hippocampal lesions do not impair learning in general, even when the learning involves retention for long periods of time. Douglas does admit that the data on humans and on animals appears to differ.

However, the results of experiments by Baddeley and Warrington (1970) give rise to doubts as to how unequivocal human research findings are, and Talland (1968) too, notes that investigations of Korsakoff patients have given rise to contradictory results. Baddeley and Warrington agree that whilst the evidence broadly suggests that the evidence favours a defective LTM, it is far from clear because most of the evidence is based on techniques which are not directly comparable with those concurrently used for studying normal memory. Using current techniques they do in fact find that long term learning of digits in one kind of task at least (Expt VI) is possible at roughly the same rate as a control group. The experiment involved presenting strings of digits in such a way that some of the strings were identical to earlier strings (The Hebb 1961 experiment). This fits in with the finding of Kimble and Pribram (1963) that monkeys with hippocampal lesions can learn, even with trials spaced six minutes apart.

As against this Baddeley and Warrington found that his amnesic patients had poorer recall in a free recall task. Differences in recall could be attributed to the items presented early in the sequence, and forming the earlier section of the serial position curve. This would indicate that a delay between presentation and test had a greater effect on amnesics than normals, and this was confirmed in a delayed recall task. Yet in a task involving sub-span units i.e. three word trigrams, an interpolated activity between presentation and recall lasting 60 seconds, still gave over 40% retention both for amnesics and controls.

It does in fact appear that for sub-span units, retention over the short term at least, is not greatly impaired, as Drachman and Arbit (1966) found, using digit sequences of varying lengths, a finding confirmed by Baddeley and Warrington. In other words, the memory span appears to be unaffected by the underlying physiological defect, whereas retention over longer periods is adversely affected. Baddeley and Warrington conclude on the basis of this, and other evidence which shows no difference between amnesics and controls, that STM is normal, an interpretation also arrived at by Wickelgren (1968).

There is evidence, however, which leads one to question whether "short term" memory is in fact unimpaired relative to long term memory. Thus Drachman and Arbit also found that memory loss was severe if a distracting task was presented between presentation and recall. Stepian and Serpinski (1964) had also found this, even in those periods where recall was normally possible, and Milner (1966) also notes the severe effects of distraction in the short term.

Various interpretations of these data are possible. It is for instance possible to argue that the effect of a distractor is to prevent rehearsal and so let the trace decay at its normal rate, the function of rehearsal being to prevent decay. Yet the effects of an interpolated task of 5 secs. duration on the first item in Baddeley and Warrington's experiment II was very small; retention was almost 80%. If prevention of rehearsal alone were responsible for the catastrophic effects of distraction one would not have expected such a high retention score. It seems more probable therefore that distractors have a positive part to play in forgetting, and as this affects forgetting within the normal "time span" for "short term memory", it is reasonable to suppose, therefore, that the deficiency is not one which involves blocking of transfer from short to long term memory. In other words it is reasonable to assume that the defect results in distractors accentuating rapid forgetting.

This last point is critical if a single system theory is to be able to handle the data. For a single system theory the answer, as given above, must be in terms of an accentuation of those factors which universally cause forgetting. Yet if one hypothesises a general increase in those factors which universally cause forgetting, why is learning alone affected? why are immediate retention and long term retention not also affected?

The discussion so far has answered this question by pointing to experimental evidence which suggests that not only is learning possible in certain types of task, (which again questions an interpretation in terms of damage to a transfer mechanism) but short term retention is also affected by certain tasks to a greater extent than is the case with control subjects. Douglas (1967), on the basis of such evidence, (particularly the evidence of disruption of "short term memory" by distractors,) suggests that the effect of the lesion is the distruction of a mechanism which suppressed interference - a suppressor mechanism.

Douglas also considers the possibility that many of the experimental results can be interpreted in terms of increased perseveration effects as a result of hippocampal lesion. A comparison of studies in which hippocampally lesioned rats showed superior performance with studies in which hippocampally lesioned rats showed inferior performance to normals could be accounted for by task differences. Where perseveration helped problem solving, hippocampally lesioned rates were inferior, and vice versa. This further suggests that the function of the hippocampus is inhibitory in nature - a suppressor mechanism.

How then, can one interpret the data in terms of universal forgetting factors being accentuated as a result of temporal lobe lesion? In order to account for the preservation of the memory span it is only necessary to postulate that forgetting factors require time or a number of items to operate.

One question remains unanswered; why is there no loss from "long term" memory if universal forgetting factors have increased? Whilst no definitive answer can be given to this, it might be that because of the non integrated nature of new material within the memory system, a lesser amount of interference is required in order to cause memory loss. For instance any material which has been preserved in the memory system for a matter of weeks must be presumed to be fairly immune to those factors which universally cause forgetting. A relatively large amount of interference or trace decay, therefore, would be necessary to cause loss, say "10" interference units. On the other hand, newly acquired information may require only "2 interference units" before forgetting takes place. In such a situation, an increase of interference in the system of 3 units would have a devastating effect on new material, but none on old material.

Summary of Chapter

It must be admitted that in many respects this chapter has been speculative, and that no unequivocal evidence to refute a dichotomous theory has been put forward. Yet this was not the aim of the chapter. It was the aim of the chapter to show that an interpretation of the "physiological" data in terms of a single system theory was equally possible, allowing that data on abnormal subjects are relevant, in any case, to questions involving normal functioning.

The first type of physiological data considered was based on experiments with electro-convulsive shock, where many investigations have shown the amnesic effects of such shock on human and animal subjects. Some studies had shown the reversibility of the amnesic effect up to about 5 seconds before shock, and on this basis it has been held that a dichotomy between short and long term memory might be justified. Yet recent evidence by Pagano et al (1969) for instance, shows the complete reversibility of amnesia and indicates that the amount of reversibility depends on the strength of the shock.

The second type of evidence was based on experiments with protein synthesis inhibitors. An analysis of evidence by Deutsch revealed that it is not at all clear whether these drugs affect memory at all, let alone short and long term memory differentially.

The third line of evidence was based on the effects of temporal lobe and hippocampal lesions on memory, where it is frequently reported that such damage affects long term learning, whereas "short" and long term memory are left intact i.e. it affects the mechanism for transferring material from short to long term memory. This line of reasoning has been questioned by Douglas (1967) for instance, who notes evidence that distraction degrades memory rapidly, within the time span of possible recall. Evidence from Baddeley and Warrington (1970) indicates that mere prevention of rehearsal is not sufficient for immediate forgetting in amnesic patients, so that the distractor tasks presumably have an active effect on forgetting. Again Baddeley and Warrington produce evidence of long term learning under certain experimental conditions.

This type of evidence leads to the suggestion that the failure to retain new information may be due to an accentuation of those factors which universally cause forgetting. The last point of the chapter tried to show how such a position could account for findings which seem problematic for a single system theory. Whilst admitting that such interpretations in terms of a single system theory are speculative, an interpretation of the data in terms of disruption of the mechanism which transfers material from short to long term memory is equally speculative in view of the empirical data considered. As such an interpretation is essential, however, for a dichotomous theory, it can reasonably be claimed that evidence based on physiological insult does not unequivocally support a dichotomous theory of memory.

CHAPTER 12

THEORETICAL POSITIONS RECONSIDERED

In Chapter 2, the theoretical positions of the following were considered: Hebb (1949) Broadbent (1963) Bower (1967) Peterson (1966a, 1966 b) Glanzer (1969) Waugh and Norman (1965) Norman (1968, 1969) Wickelgren (1969) Weiskrantz (1967) Adams (1967) Atkinson and Shiffrin (1968) Tulving (1968). These positions are now considered in turn in the light of the subsequent analysis and evidence of the thesis. Only the main aspects of their theoretical positions are discussed.

1. Hebb's and Broadbent's theoretical position. The theoretical position of Hebb (1949) and Broadbent (1963) rests on the assumption that autonomous trace decay underlies short term forgetting. Whilst it is possible that this is the case, it is also possible that all forgetting is due to autonomous trace decay, in which case a dichotomy between short and long term memory is untenable. As was noted in Chapter 4, the basis for claiming that "STM" was subject to autonomous trace decay rests on the evidence that forgetting is sometimes rapid, whereas once material is well rehearsed its forgetting is slow if not absent. Again it is claimed e.g. Broadbent (1963) that forgetting over the short term is not subject to associateive interference, as it is in the long term. Whilst the first argument merely poses the cause of rapid forgetting - rapid forgetting might be due to factors which universally cause forgetting - Melton (1963) and Keppel and Underwood (1962) have shown the importance of other items for forgetting in the short term and Wickelgren (1965a) and Corman and Wickens (1968) have shown the effects of similarity of materials on forgetting in the short term. On the

surface, therefore, autonomous trace must be abandoned in favour of interference. As Brown (1958) has argued however, autonomous trace decay can account for the effects of similarity on forgetting in that interference may be the result, not the cause of forgetting of an underlying trace. As was pointed out in Chapter 6, however, to take this position entails the possibility that all forgetting, whether in the short or the long term, is due to autonomous trace decay, and this makes a dichotomous theory untenable.

The psychological evidence, then, does not unequivocally support a dichotomous theory in which short term forgetting is due to autonomous trace decay whereas long term forgetting is due to associative interference.

Bower's theoretical position

The interesting aspect of Bower's (1967) theoretical position is the clear statement he makes as to the criterion for distinguishing short and long term memory, short term memory being labile, long term memory being stable. He relies on evidence of the effects of shock on newly acquired material to indicate a distinction between short and long term memory (e.g. P 122.) The evidence reviewed in Chapter 11, however, indicates that this type of evidence is by no means unequivocal, in that recovery of newly acquired information following shock is possible (after amnesia) providing the extent of the shock is not too gfeat, as is the case with "long term" material, which is also subject to amnesic effects following shock (e.g. ECS).

Bower also regards items as residing in STM at the risk of being lost in an all or nothing manner, unless rehearsal results in it being copied into long term memory. Expt. 1 and 2 of this thesis

(Chapter 7) on the limited capacity hypothesis, whilst not perhaps fatal for this formulation, are an embarrassment, in that a large amount of material was retained following a single exposure at a rate which can reasonably be taken to exclude the possibility of rehearsal. In that Bower regards LTM as a stable system, the forgetting of items such that recognition only was possible must have taken place in STM. It is difficult to see that items which could only be recognised but not recalled could be rehearsed, (at least in the normal sense of the word) and transferred to long term memory. This is a particularly embarrassing point if it is claimed that forgetting of items in STM is an all or nothing manner, as Bower does, and that the long-short model has no natural way to accomodate within its conceptual framework any distinction between recognition and recall.

Peterson's theoretical position

Peterson (1966 a, b) like Hebb and Broadbent, is a decay theorist, holding that the difference between auditory and visual presentation effects in the experiment of Keppel and Underwood (1962) indicates that trace decay operates over the short term, but may be masked by interference effects which also occur. Specifically the fact that the first item visually presented did not show decay is taken to indicate the operation of trace decay in the former situation. Chapter 6 pointed to various other possible interpretations in terms of interference theory, and perhaps a more major objection is that if trace decay operates in the short term along with interference, on what grounds can it be claimed that it is absent from long term memory, rather than being difficult to detect over the longer term.

Other evidence which Peterson uses is based on the different reactivity of sections of the serial position curve to different variables. The most recent part of the serial position curve reacts differently to the early and middle part of the serial position curve as a result of such variables as rate of presentation, interpolation of activity between presentation and recall etc.

Chapter 10 involved an analysis of the serial position curve. It was conceded that the evidence was compatible with a dichotomous theory of memory, although for the most part it involved restating evidence produced by other means. It was also pointed out, however, that the evidence was compatible with a single system theory, and that furthermore, the generality of findings based on serial position curve evidence was open to the most serious doubts. This questioning of generality arose out of experiments on acoustic onfusion, which Craik (1968) and Kintsch and Buschke (1969) had shown to affect only the recency part of the serial position curve. Yet as Baddeley and Warrington (1970) admit, and as experiments in the cour se of this thesis (Chapter 8) and elsewhere have shown, acoustic confusions do occur in the long term, and furthermore long term storage must logically involve acoustic storage. Therefore evidence based on the serial position curve is not necessarily indicative of a dichotomy, effects in the short and long term may be present but weak, or counteracted by other variables which alter in strength over the short and long term.

Furthermore, evidence which Peterson puts forward in support of a dichotomous theory, and based on serial position curve effects, involves reminiscence effects. Peterson (1966 c) showed that the last few items showed a reminiscence effect when their recall probabilities were compared immediately after presentation, and a short time after presentation. Peterson interpreted this in terms of switching from one retrieval mechanism to another. Yet, whilst a possible interpretation, the evidence does not entail a dichotomy in that both interference theory and autonomous trace decay theory can also account for the data. (See Chapter 6).

Finally Peterson's evidence for a dichotomy based on evidence of a recency mechanism which inhibited only the production of responses recently given, was seen to be merely a restatement that rapid forgetting occurs. It is in other words an operational consequence of rapid forgetting for which a dichotomous theory of memory is only one possible explanation.

Glanzer's theoretical position

As was noted in Chapter 2, Glanzer's theoretical position has changed somewhat since his first theoretical paper, on a dichotomous theory of memory. (Glanzer and Cunitz 1966). He now considers short term forgetting is due to non associative factors, particularly displacement of items in the short term store by later incoming items.

The empirical evidence upon which Glanzer rests his theoretical position comes entirely from studies of the effect of variables on the shape of the serial position curve. Evidence that interpolation of activity between presentation and recall affects the recency part but not the earlier part of the serial position curve, for instance, is taken as evidence of the effects of this variable on short but not long term memory.

The empirical objections to Glanzer's position have already been noted in this chapter. The evidence on acoustic confusion indicates that free recall studies involving the serial position curve have no special status in establishing a dichotomous theory of memory, and the evidence that only the number of items not their relationship causes short term forgetting, is even refuted by serial position curve studies. (See Chapter 10). Furthermore, as was noted in Chapter 6, a trace decay model for STM is not negated by this type of evidence.

Waugh and Norman's theoretical position

The evidence upon which Waugh and Norman (1965) base a dichotomous theory is in many ways similar to other dichotomous theorists already discussed e.g. Glanzer et al (1969). As well as basing their conclusions on the evidence that the shape of the serial position curve is differentially affected by such variables as repetition, Waugh and Norman, like Glanzer et al, claim that the short term element is affected by the number of items interpolated between presentation and recall, unlike secondary memory.

As far as basing a dichotomy on the evidence from free recall studies is concerned, objection to this has already been considered. Yet for theories which claim an overlap between short and long term memory, such that the recency position of the curve indicates output from both short and long term memory, at least one experiment based on free recall is a particular embarrassment. The experiment of Baddeley and Warrington (1970) which failed to show differences between amnesic subjects with "impaired LTM" and control subjects for the recency part of the curve raises questions as to whether the recency part of the curve can have any "long term memory" component. /

That the "long term" memory component is not affected by

/ Footnote: The term "impaired LTM" is somewhat inaccurate; it would be better to talk of impaired learning capacity, as LTM per se is not claimed to be impaired.

interpolation of items between presentation and recall whereas the "short term" component is affected, can hardly be taken as definitive evidence of a dichotomy. As was noted above and in Chapter 6, the evidence upon which such a claim is made does not preclude the possibility of autonomous trace decay in the short term. Again, serial position curve experiments may be too insensitive to measure loss due to interpolation of items in "long term memory". It is, after all, too insensitive to measure acoustic confusion!

The "echo box" argument, used by Waugh and Norman, (i.e. introspective evidence of the fleeting nature of such of our experience, to gether with the introspective evidence that we rarely fail to recall the last few items of a sentence, and can "parrot" them back) was noted to be merely a statement that forgetting is sometimes rapid, which is of course not in dispute. The implication that material enters a short term box, is later rejected by Norman himself (1968) because of the necessity of postulating massive interaction between "short" and "long" term memory.

Norman's theoretical position

Norman's theoretical writings (1968), 1969) carry little evidence of conviction over the question of a dichotomous theory of memory, as has been noted in Chapter 2. He admits that a formal distinction between the two systems is difficult to make, and admits too (1969) P 88, "It is of course very difficult to distinguish a theory which postulates decay in time from one which postulates decay caused by interference, because it is not possible to do the one critical experiment which everyone would accept." The discussion in Chapter 4 made it clear that such a distinction is at the heart of the resolution of the present problem.

Norman (1968) does, however, hold a dichotomous theory of sorts, on the basis of differing interference effects as between short and long term memory. The experimental evidence and the review of the literature on this topic however, in Chapter 9, makes the holding of a dichotomous theory of memory on this basis, untenable.

Wickelgren's theoretical position

Wickelgren's theoretical position rests basically on two lines of evidence; evidence of differing decay rates over periods of time for differing materials, and physiological evidence based on amnesic patients.

Wickelgren (1965 a) does himself state the objection to inferring a dichotomous theory of memory from evidence of differing decay rates over time P 53 "On the contrary if interference in STM can be shown to depend on the nature of interfering activity in the same way as in LTM, then it will be plausible to assume that STM and LTM are performed by the same system operating in a qualitatively different manner under different degrees of learning." It follows from this that one will have different decay rates for different materials, which makes the inference of a dichotomy on the evidence of different decay rates untenable. Wickelgren goes on in that paper to show the effects of associative interference in the short term (as in the long term).

The central issue is whether one or a few instances are enough on which to draw conclusions, concerning evidence of interference effects in the short term. The argument put forward in Chapter 4 was that if it is merely possible that rapid and less rapid forgetting cah have the same cause, then it becomes impossible to be sure that rapid forgetting does not take place in "LTM". Even if, for certain types of material (e.g. acoustically related material or material in the centre of a supra span list) forgetting is always rapid, this does not entail a dichotomy. Certain types of material may be especially susceptible to those factors which universally caus e forgetting, because of the relationship of this material to the rest of the cognitive framework.

The physiological evidence upon which Wickelgren relies has been criticised in Chapter 11. Whilst evidence of learning impairment is awkward for a single system theory, particularly the evidence which Wickelgren (1968) himself puts forward, the evidence of the effect of distractors on retention is awkward for a dichotomous theory, at least to the extent that it allows a single system theory interpretation of the data.

Wickelgren (1969 a) does differ from many other dichotomist theorists in denying a distinction between short and long term memory on the basis of acoustic coding being confined to short term memory. Indeed he predicts empirical evidence in support of acoustic coding in long term memory. Furthermore he is not convinced of the evidence denying a role to semantic processing in short term memory, and quotes many of the same studies quoted by Gruneberg and Sykes (1969 a) which indicate semantic coding in short term memory. Whilst it is fair to point this out, it must be admitted that his position has not always been clear, as was noted in Chapter 9.

Weiskrantz's theoretical position

Weiskrantz's theoretical position rests on evidence that electro convulsive shock has irreversible effects over the short but not the long term. Recent evidence of Pagano et al (1969) however, casts serious doubts on this view. They have shown that amnesia following shock might well be completely reversible, provided the shock is not too great.

Even without the evidence of Pagano et al, however, the evidence does not force a dichotomous position. Permanent forgetting might still be due to an increase in those factors which universally cause forgetting. New material may be susceptible to forgetting factors because it has not been adequately integrated within the memory system.

Adams' theoretical position

Adams' theoretical position rests on three lines of evidence: physiological evidence, the limited capacity to take in new information, and differing coding systems employed over the short and the long term.

Chapter 11 dealt with the physiological evidence, indicating that it did not force a dichotomous theory. Chapters 7 and 8 dealt with the limited capacity hypothesis, indicating that limited capacity to take in new information did not of itself entail a dichotomous theory of memory, and Chapter 9 indicated that a dichotomous theory could not be established on the basis of evidence which purports to show that short and long term memory employ different coding systems.

Further objections have been raised against Adams' theoretical position. His claim that interference accounts for forgetting in both short and long term memory entails the collapse of a dichotomous theory because of the empirical impossibility of distinguishing between greater susceptibility of certain materials to those factors which cause forgetting i.e. interference and two different memory systems. For instance acoustic confusion occurs to a greater extent over the short than the long term, whereas semantic confusion is the other way round. It is impossible to establish whether this indicates the greater susceptibility of acoustic material to those factors which universally cause forgetting, or whether acoustic coding is confined to one system, semantic coding to another. (This makes the unwarranted assumption that the evidence supports such a dichotomy in any case.)

That Adams allows rapid forgetting per se is not necessarily a characteristic of STM also entails the collapse of a dichotomous theory of memory, as has been pointed out previously. This is because rapid forgetting is the criterion by which one decides whether material is in one system or another.

Finally, Adams' views on the relationship between recognition and recall, in which he views the relationship as involving dichotomous memory systems, is seen to be unparsimonious in Chapter 5.

Atkinson's and Shiffrin's theoretical position

As the theoretical statement of a dichotomy by Atkinson and Shiffrin (1968) is more explicit than any other, it is important to high light the fatal weaknesses in their formulation.

The greatest weakness in their formulation concerns the possibility that material can be transferred from short to long term memory without the intervention of a central process such as rehearsal. This entails the possibility that any material retrieved may be retrieved from LTM. Together with the admitted possibility (P 127), that rapid forgetting can take place in LTM, this theory is indistinguishable from one which claims that all material enters one memory system (LTM) where rapid forgetting can take place due to those factors which universally cause forgetting. This possibility is supported by evidence that associative interference causes both rapid and less rapid forgetting, and that autonomous trace decay cannot be shown to operate only over the short term.

There is, in fact, in Atkinson and Shiffrin's own writing, a great deal of equivocation over the relationship between short and long term memory. At one point (P 115) they admit that information entering STS comes from LTS, which as pointed out before, entails material entering LTS directly, and presumably being forgotten from LTS. How is it lost from LTS, if LTS does not involve a mechanism in which material is subject to trace decay through displacement?

There is one other major area in their formulation which is subject to direct empirical disproof. They claim, P 111 and P 128, that the function of rehearsal is to regenerate the STS and prolong decay and that the longer an item is in STS, the greater will be its strength in long term memory. Yet Glanzer and Meinzer (1967) have shown that repeating an item reduces its long term retention. Indeed their own empirical evidence confirms this.

As Atkinson and Shiffrin base their case on the explanatory power of their theory, these weaknesses must be regarded as fatal for the theory in its present form, at least.

<u>Tulving's theoretical position</u>

Tulving's (1968) theoretical position differs from other dichotomous theorists in that he does not consider a dichotomy of storage systems justified by the empirical data, but instead supports a dichotomy of retrieval systems in the complete absence of supportive data. His suggestion that acoustic cues aiding retrieval are confined to short term memory receives no empirical support from the literature,

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<u>Footnote</u>: Like Wickelgren, Atkinson and Shiffrin do not entertain the possibility of a dichotomy on the basis of differing coding systems as between short and long term memory.

and indeed evidence of acoustic confusion in LTM makes such a hypothesis untenable. The view that STM is limited in retrieval capacity whereas LTM is relatively unlimited has been shown to be untenable, at least as the basis for holding a dichotomous theory of memory. Finally his views on recognition and recall being dichotomous states are seen to be unparsimonious (Chapter 5). Tulving and Madigan (1970) recently undertook an analysis of the contribution of publications to knowledge in the field of memory. As two thirds of the papers considered were classified as "utterly inconsequential", it is reasonable to assume that Tulving's own contributions to knowledge lead the majority.

The Writer's theoretical position

The writer's theoretical position can now be explicitly stated. Material, once post-categorised is in a memory system in which various possible processes result in forgetting. Forgetting will vary in rate according to factors which relate newly acquired material to older material within the memory system.

Older material will have survived the influences of those factors which result in forgetting, and will be less susceptible therefore to any increase in universal forgetting factors than will newly acquired material which is still in a relatively unintegrated state. Rapid forgetting of newly acquired material may be inhibited however, by increasing the rate of integration, through such control processes as rehearsal, which will then tend to lessen the susceptibility of newly acquired material to forgetting.

Differences in forgetting rates for different types of material e.g. acoustically and semantically related materials can be accounted for by differences in susceptibility to forgetting, of the materials. This may be because acoustic material is less well integrated in the memory system.

It is not claimed that this is an original position or the only possible interpretation of the data, or that all the data have been satisfactorily explained in terms of this theoretical framework. It is claimed that, being the more parsimonious model of memory, it must be disproved, if a dichotomous theory is to have currency.

CHAPTER 13

SUMMARY

This thesis has been concerned with an analysis of differences between short and long term memory, and has tried to show that the holding of a dichotomous theory of memory is, at this stage of our knowledge, at least, unjustified. It is also the writer's view that a dichotomous theory of memory is unprovable, so that one must accept the more parsimonious single system theory of memory.

The thesis began by outlining the various approaches and theories of those maintaining a dichotomous theory of memory (Chapter 2), and those holding a single system theory (Chapter 3.) There followed then (Chapter 4) an analysis of the major problems confronting a dichotomous theory of memory, in particular its reliance on evidence that rapid forgetting could distinguish short and long term memory. The following chapter (Chapter 5) looked at the further theoretical problem of the relationship between recognition and recall, and concluded that a dichotomy between recognition and recall was not called forth by the evidence. This, it was noted, had implications of both a methodological and theoretical nature, in particular it made unnecessary a dichotomy between short and long term recognition memory as distinct from a short and long term recall memory.

The rest of the thesis concerned itself with the empirical evidence which is claimed to support a dichotomous theory. Chapter 6 looked at the psychological evidence on the nature of forgetting, and it was concluded that no theory of forgetting could be shown conclusively to operate in the short but not in the long term, a point which is fatal for the establishment of a dichotomous theory of memory.

Chapters 7 and 8 looked at the evidence for a dichotomy based on the limited capacity hypothesis, and it was concluded that this cannot be used to establish a dichotomous theory of memory. Indeed it was thought (Chapter 8) that the experimental evidence produced by the writer was an acute embarrassment to dichotomous theorists.

Chapter 9 considered the evidence for a dichotomous theory of memory based on different interference effects in short and long term memory, from which it is inferred that short term memory uses acoustic coding and long term memory semantic coding. Experimental evidence produced in the course of the thesis contradicted this position, and a logical analysis revealed its logical weakness.

Chapter 10 involved an analysis of the serial position curve, and it was concluded that such evidence is for the most part merely a restatement of other findings, which poses the question of the cause of rapid forgetting, but does not answer it. The generality of findings based on the serial position curve was also questioned.

Chapter 11 considered the physiological evidence for a dichotomous theory of memory, and it was noted that the evidence could not be taken as establishing a dichotomous theory of memory. Not only is it dubious that evidence which depends on insult or injury is relevant to normal functioning, the evidence itself, whether from studies of the effects of drugs, of electro convulsive shock or of hippocampal lesion, did not force an interpretation of memory in terms of two separate systems.

Chapter 12 returned to view the various theories supporting dichotomy of memory systems, in the light of the evidence presented in the course of the thesis. No theory appeared able to stand up, at least in its present form, to the evidence presented.

A dichotomous theory of memory then, appears to be unproved and unprovable. It is unproved because no single line of evidence unequivocally supports a dichotomous theory of memory, to the exclusion of single system theory explanations. It is unprovable because proof depends on showing different mechanisms of forgetting over time. As long as this cannot be demonstrated, and such writers as Hilgard and Bower (1966) consider this a serious possibility, then a dichotomous theory becomes unprovable. One cannot argue, as Adams (1967) has, that different forms of the same mechanism underly short and long term memory, because one cannot empirically distinguish between differing susceptibility to those factors which universally cause forgetting for different materials, and different underlying memory mechanisms. As long as different mechanisms of forgetting over time cannot be proved, a dichotomous theory of memory is unprovable.

In conclusion, the writer would like to suggest what he regards as the main contributions of this study of memory.

1. It has been demonstrated that one cannot establish a dichotomy on the basis of the limited capacity to take in new information. Many writers are of course sceptical about the value of the memory span as indicating capacity limits of short term memory, but none, as far as the writer is aware, has gone so far as to demonstrate that a dichotomous theory cannot be established on the basis of the limited capacity to take in new information.

2. It has been demonstrated that one cannot dichotomise on the basis of differing coding systems as between short and long term memory, specifically that acoustic coding is confined to short term memory, semantic coding to long term memory.

3. It has been demonstrated that evidence for a dichotomy based on the serial position curve is not sufficient to establish a dichotomy, in that single system theory explanations are as parsimonious.

4. It has been demonstrated that if short and long term memory are both subject to the same forgetting process, then a dichotomy between short and long term memory cannot be established.

To what extent the writer has succeeded in establishing a single system theory of memory remains to be seen. Whatever the response to the main conclusion that a single system theory must be held, it is hoped that those holding a dichotomous theory of memory will at least respond to the objections and problems raised in the thesis, so that an advance, one way or the other, can be made. This writer is not concerned with establishing a lied, and hopes that enough real problems for a dichotomous theory have been raised to protect him from the charge of being "crankily in opposition", to use Bruner's phrase.

BIBLIOGRAPHY

Aaronson, D. (1966) Temporal factors in perception and short term memory. Psychol. Bull. 67, 130 - 144.

Adams, J.A. (1967) Human Memory. McGraw-Hill, New York.

Agranoff, B.W. and Klinger P.D. (1964) Puromycin effect on memory fixation in the Goldfish. Science 146, 952 - 953.

Allen, L.R. and Gorten R.F. (1968) The influence of word knowledge on the word-frequency effect in recognition. Psychon. Sci., 10, 401-402.

Annisfeld, M. and Knapp, M. (1968) Association, synonymity and directionality in false recognition. J. Expt. Psychol. 77, 171 - 179.

Baddeley, A.D. (1964) Semantic and Acoustic similarity in short term memory. Nature 204, 1116 - 1117.

Baddeley, A.D. (1966a) The influence of acoustic and semantic similarity on long term memory for words. Quart. J. Expt. Psychol. 18, 302 - 309.

Baddeley, A.D. (1966b) Short term memory for word sequences as a function of acoustic, semantic and formal similarity. Quart. J. Expt. Psychol. 18, 362 - 365

Baddeley, A.D. (1968) Prior recall of newly learned items and the recency effect in free recall. Can. J. Psychol. 22, 157 - 163.

Baddeley, A.D. and Dale, H.C.A. (1966) The effect of semantic similarity on retroactive interference in Long and Short term memory. J. Verb. Learn. Verb. Behav. 5, 417 - 420.

Baddeley, A.D., Scott, D., Drynan, R. and Smith, J.C. (1969) Short term memory and the limited capacity hypothesis. Brit. J. Psychol. 60, 51 - 56.

Baddeley, A.D. and Warrington, E.K. (1970) Amnesia and the distinction between long and short term memory. J. Verb. Learn. Verb. Behav. 9, 176 - 189.

Bahrick, H.P. (1964) Retention curves: facts or artifacts. Psychol. Bull. 61, 188 - 194.

Bahrick, H.P. (1969) Measurement of retention by prompted recall. J. Expt. Psychol. 79, 213 - 219.

Bahrick, H.P. and Bahrick, P.O. (1964) A re-examination of inter-relations among measures of retention. Quart. J. Expt. Psychol. 16, 318 - 324.

Barbizat, I (1963) Defect of memorising of hippocampal - mammillary origin. J. of Neurol. Neurosurgery and Psychiat. 26, 127 - 135.

Barondes, S.H. and Cohen, H.D. (1966) Puromycin effects on successive phases of memory storage. Science 151, 594 - 5.

Barondes, S.H. and Cohen, H.D. (1967) Comparative effects of Cyclohexamide and puromycin on cerebral protein synthesis and consolidation of memory in mice. Brain Res. 4, 44 - 51.

Blankenship, A.B. (1938) Memory span, a review of the literature. Psychol. Bull. 35, 1 - 25.

Borkowski, J.G. and Eisner, H.O. (1968) Meaningfulness and Abstractness in short term memory. J. Expt. Psychol. 76, 57 - 61.

Bower, G.H. (1964) In "The psychology of learning and motivation - advances in research and theory" Vol. 1. Ed. Spence K.W. and Spence, J.T. Academic Press, New York.

Bower, G.H. (1967) In "The organisation of Recall" Ed. Kumble, D.P. New York Academy of Sciences.

Bower, G.H., Clark, M.C. Lesgold, A.M. and Winzenx, D. (1969) Hierarchial Retrieval Schemes in Recall of Categorised Words. J. Verb. Learn. Verb. Behav. 8, 323 - 343.

Bremner, L.R. (1940) An experimental investigation of memory span. J. Expt. Psychol. 26, 467 - 482.

Broadbent, D.A. (1958) Perception and Communication. Pergammon Press, London.

Broadbent, D.A. (1963) Flow of information within the organism. J. Verb. Learn. Verb. Behav., 2, 34 - 39.

Broadbent, D.A. (1967) In "The organisation of Recall" (ed.) Kimble, D.P. New York, Academy of Sciences.

Brown, J. (1958) Some test of the decay theory of immediate memory. Quart. J. Expt. Psychol. 10, 12 - 21.

Brown, J. (1959) Information, redundancy and decay of memory trace. In "The mechanisation of thought processes". London. H.M. Stationery Office.

Brown, J. (1964) Short term memory. Brit. Med. Bull. 20, 8 - 11.

Brown, J. (1965) A comparison of recognition and recall by a multiple response method. J. Verb. Learn. Verb. Behav. 4, 401 - 408.

Brown, J. and Packham, D.W. (1967) The effect of prior recall on multiple response recognition. Quart. J. Expt. Psychol.

Brown, R. and McNeil, D. (1966) The "tip of the tongue" phenomenon. J. Verb. Learn. Verb. Behav., 5, 325 - 337.

Bruce, D. and Crowley, J.J.(1970) Acoustic similarity effects on retrieval from secondary memory. J. Verb. Learn. Verb. Behav. 9, 190 - 196.

Calfee, R.C. and Peterson R.E. (1968) Effects of list organisation on short term probe recall. J. Expt. Psychol. 77, 468 - 474.

Chorover, S.C. and Schiller, P.H. (1965) Short term retrograde amnesia in rats. J. Comp. Physiol. Psychol. 59, 73 - 78.

Clark, H.J. (1965) Recognition memory for random shapes as a function of complexity, association value, and delay. J. Expt. Psychol. 69, 590 - 595.

Cofer, C.W., Segal, E. Stein, J. and Walker, H. (1964). Studies on free recall of nouns following presentation under adjectival conditions. J. Expt. Psychol. 79, 254 - 64.

Cohen, H.D., Ervin, F. and Barondes, S.H. (1966) Puromycin and Cyclohexamide: Different effects on hippocampal electrical activity. Science 154, 1557 - 1558.

Cohen, R.L. and Johansson, B.O.S. (1967) The activity trace in immediate memory. J. Verb. Learn. Verb. Behav. 6, 139 - 143.

Conrad, R. (1958) Accuracy of recall using Keyset and Telephone dial and the effect of the prefix digit. J. Appl. Psychol. 42, 285 - 288.

Conrad, R. (1960) Very brief delay of immediate recall. Quart. J. Expt. Psychol., 12, 45 - 47.

Conrad, R. (1964) Acoustic confusions in immediate memory. Brit. J. Psychol, 55, 75 - 84.

Conrad, R. (1967) Interference or decay over short retention intervals. J. Verb. Learn. Verb. Behav. 6, 49 - 54.

Conrad, R. and Hille, B.A. (1958) The decay rate of immediate memory and paced recall. Can. J. Psychol. 12, 1 - 6.

Conrad, R. and Rush, M.C. (1965) On the nature of short term memory encoding by the deaf. J. Speech Hearing Disord. 30, 336 - 343.

Corballis, M. (1966) Rehearsal and decay in immediate recall of visually presented material. Can. J. Psychol, 20, 43 - 51.

Corman, C.D. and Wickens, D.D. (1968) Retroactive inhibition in short term memory. J. Verb. Learn. Verb. Behav. 7, 16 - 19.

Crannel, C.W. and Parrish, J.M. (1957) A comparison of immediate memory span for digits, letters and words. J. Psychol., 44, 319 - 327.

Craik, F.I. (1968) Types of error in free recall. Psych. Sci. 10, 353 - 4.

Craik, F.I. (1970) The fate of primary memory items in free recall. J. Verb. Learn. Verb. Behav. 9, 143 - 148.

Crowder, R.G. (1968) The relationship between interpolated task performance and proactive inhibition in short term memory. J. Verb. Learn. Verb. Behav. 7, 557 - 583.

Dale, H.C.A. and Baddeley, A.D. (1962) Alternatives in testing recognition memory. Nature, 172, 93.

Dale, H.C.A. and Gregory, M. (1965) Evidence of semantic coding in short term memory. Psych. Sci. 5, 75 - 76.

Dalrymple - Alford (1967) Repetition and Immediate Memory. Brit. J. Psychol., 58, 63 - 67.

Davies, R., Sutherland, W.S. and Judd, B.R. (1961) Information content in recognition and recall.

Deese, J. (1956) — Complexity of contour in the recognition of visual form. Quoted Adams, J.A. Human Memory (1967) McGraw Hill.

Deese, J. (1963) — In Cofer, C.N. and Musgrave, B.S. (Eds.) Verbal behaviour and learning. McGraw Hill, N. York.

Deese, J. and Kaufman, R. (1957) — Serial effects in recall of unorganised and sequentially organised material. J. Expt. Psychol. 54, 180 - 187.

Deutsch, J.A. (1969) — The physiological basis of memory. Ann. Rev. of Psychol., 85 - 104.

Douglas, R.J. (1967) — The hippocampus and behavior. Psychol. Bull., 67, 416 - 442.

Drachman, D.A. and Arbit, J. (1966) — Memory and the hippocampal complex. Archives of Neurol. 15, 52 - 61.

Eagle, M.N. (1967) — The effect of learning strategies upon free recall. Am. J. Psychol. 80, 421 - 5.

Earhard, M. (1968) — The facilitation of memorisation by alphabetic instruction. Can. J. Psychol. 21, 15 - 24.

Ekstrand, B. (1965) — Effect of sleep on memory. J. Expt. Psychol., 75, 64 - 72.

Feigenbaum, E.A. (1967) — In "The organisation of recall" Ed. Kimble, D.P.; New York, Academy of Sciences.

Field, W.H. and Lechman, R. (1966) — Information transmission and recall as a function of alternatives. J. Expt. Psychol., 72, 785 - 791.

Flexner, L.B. and Flexner, J.B. (1967) — Restoration of expression of memory lost after treatment with puromycin. Quoted Deutsch, A.R. (1969) op. cit.

Flexner, L.B., Flexner, J.B. and Roberts, R. (1967) Memory in mice analysed with antibiotics. Science 155, 1377 - 1383.

Freund, R.D. Brelsford, J.W. and Atkinson, R.C. (1969) Recognition v. recall. Quart. J. Expt. Psychol., 21, 214 - 224.

Glanzer, M. (1969) Distance between related words in free recall: Trace of the STS. J. Verb. Learn. Verb. Behav. 8, 105 - 111.

Glanzer, M. and Cunitz, A.R. (1966) Two stage mechanisms in free recall. J. Verb. Learn. Verb. Behav. 5, 351 - 360.

Glanzer, M. and Meinzer, A. (1967) The effects of intralist activity on free recall. J. Verb. Learn. Verb. Behav. 6, 928 - 935.

Glanzer, M., Gianutsos, R. and Dubin, S. (1969) The removal of items from short term storage. J. Verb. Learn. Verb. Behav. 8, 435 - 437.

Goggin, J. (1966) Retroactive and proactive inhibition in the short term retention of paired associates. J. Verb. Learn. Verb. Behav. 5, 526 - 535.

Gorman, A.M. (1961) Recognition memory for nouns as a function of abstractness and frequency. J. Expt. Psychol. 61, 23 - 29.

Gruneberg, M.M. (1969a) Theoretical note: logical objections to a dichotomous theory of memory. Psychol. Reps. 24, 606.

Gruneberg, M.M. (1969b) The limited capacity hypothesis and short term memory. Acta Psychol. 31, 326 - 339.

Galanter, E. (1967) In "The organisation of Recall" ed. Kimble, D.P., N. York Academy of Sciences

Gruneberg, M.M. and Sykes, R.N. (1969a) Semantic and Acoustic coding in short and long term memory. Psych. Reps. 25, 849 - 850.

Gruneberg, M.M. and Sykes, R.N. (1969b) Acoustic confusion in long term memory. Acta Psychol., 31, 293 - 296.

Gruneberg, M.M., Colwill, S.J., Winfrow, P. and Woods, R.W. (1970). Acoustic confusion in long term memory - an extension of previous findings. Acta Psychol. In press.

Hannawalt, N.G. and Tarr, A.G. (1961) The effect of recall upon recognition. J. Expt. Psychol., 62, 361 - 367.

Harrison, G.J. (1967) Some additive results in short term memory. Acta Psychol., 27, 306 - 315.

Hebb, D.O. (1949) Organisation of Behavior. John Wiley and Sons. N. York.

Hebb, D.O. (1961) In "Brain mechanisms and learning" in ed. Delafresnaye. Blackwell, London.

Hebb, D.O. and Foord, E.N. (1945) Errors of visual recognition and the nature of the trace. J. Expt. Psychol., 35, 335 - 348.

Henley, N.M., Noyes, H.L., and Deese, J. (1968) Semantic structure in short term memory. J. Expt. Psychol., 77, 587 - 592.

Hilgard, E.R. and Bower, G.H. (1966) Theories of Learning. Appleton Century Crofts. N. York.

Hintzman, D.L. (1967) Articulatory coding in short term memory. J. Verb. Learn. Verb. Behav. 6, 312 - 316.

Ingles, J. and Ankus, M.N. (1965) Effects of age on short term storage and serial learning. Brit. J. Psychol. 56, 183 - 195.

Gruneberg, M.M. (1970) A dichotomous theory of memory - Unproved and Unprovable? Acta Psychol. In press.

Jacobson, C.F. (1936) Studies of cerebral function in primates. 1. The function of the frontal association areas in monkeys. J. Comp. Physiol. Psychol., 13, 3 - 60.

Jahnke, J.C. and Erlick, D.E. (1968) Delayed recognition and the serial organisation of short term memory. J. Expt. Psychol. 77, 641 - 647.

James, W. (1890) The principles of psychology. Holt, New York.

Jarvick, M.E. and Kopf, R. (1967) Transcorneal electroconvulsive shock and retrograde amnesia. J. Comp. Physiol. Psychol, 64, 431 - 33.

Jenkins, J.G. and Dallenbach, K. (1924) Oblivisence during sleep and waking. Am. J. Psychol. 605 - 612.

Johnson, L.M. (1933) Similarity of meaning as a factor in retroactive inferference. J. General Psychol, 9, 377 - 389.

Jung , U.(1968) Verbal Learning. Holt, Rinehart and Winston, N.York.

Kay, H. and Skemp, R. (1956) Different thresholds for recognition - further experiments on interpolated recall and recognition. Quart. J. Expt. Psychol. 8, 153 - 162.

Keppel, G. (1965) Problems of method in the study of short term memory. Psych. Bull. 63, 1 - 13.

Keppel, G. (1968a) In "Verbal behaviour and General behaviour theory" ed. Dixon, T.R. and Horton, D.L. Prentice Hall, Englewood Cliffs.

Keppel, G. (1968b) Verbal Learning and Memory. Ann. Rev. of Psychol., 19, 169 - 202.

Keppel, G. and Underwood, B.J. (1962)
Proactive inhibition in short term retention of single items. J. Verb. Learn. Verb. Behav. 1, 153 - 161.

Kimble, D.P. and Pribram, H.K. (1963)
Hippocampectomy and behavior sequences. Science, 139, 824 - 5.

Kintsch, W. (1968)
Recognition and free recall of organised lists. J. Expt. Psychol., 78, 481 - 487.

Kintsch, W. and Buschke, H. (1969)
Homophones and Synonyms in Short Term memory. J. Expt. Psychol., 80, 403 - 407.

Lachman, R. and Tuttle, A.V. (1965)
Approximation to English and short term memory, construction or storage? J. Expt. Psychol., 70, 386 - 393.

Lachman, R., Laughery, K.L. and Field, W.H. (1966).
Recognition and recall of high frequency words following serial learning. Psychon. Sci. 4, 225 - 6.

Landauer, T.K. and Freedman, J.L. (1968)
Information retrieval from long term memory: Category size and recognition time. J. Verb. Learn. Verb. Behav. 7, 291 - 295.

Light, L.L. and Carter-Sobell, L. (1970)
Effect of changed semantic context on recognition memory. J. Verb. Learn. Verb. Behav. 9, 1 - 11.

Lloyd, K.E. (1964)
Short term retention as a function of word frequency. J. Verb. Learn. Verb. Behav. 3, 286 - 289.

Loess, H. (1968)
Short term memory and item similarity. J. Verb. Learn. Verb. Behav. 7, 87 - 92.

Loess, H. and Harris, R. (1968) Short term memory for individual verbal items as a function of method for recall. J. Expt. Psychol., 78, 64 - 69.

Mackworth, J.F. (1962) Presentation rate and memory. Can. J. Psychol., 16, 42 - 47.

Martin, E., Roberts, K.H., and Collins, A.M. (1968) Short term memory for sentences. J. Verb. Learn. Verb Behav. 7, 560 - 566.

McGauch, J.A. (1967) In "The organisation of recall" Ed. Kimble, D.P. N. York Academy of Sciences.

McGeoch, J.A. (1932) Forgetting and the law of disuse. Psychol. Rev. 39, 352 - 370.

McGeoch, J.A. (1942) The psychology of human learning. Longman Green, N. York.

McGeoch, J.A. and McDonald, W.T. (1931) Meaningful relations and retroactive inhibition. Am. J. Psychol., 43, 579 - 588.

McGhee, A., Chapman, J. and Lawson, J.S. (1965) Changes in immediate memory with age. Brit. J. Psychol., 56, 69 - 75.

McKinney, F. (1935) Retroactive inhibition and recognition memory. J. Expt. Psychol., 18, 585 - 598.

McNulty, J.A. (1965) An analysis of recall and recognition processes in verbal learning. J. Verb. Learn. Verb. Behav. 4, 430 - 436.

McNulty, J.A. (1966) A partial learning model for recognition memory. Can. J. Psychol., 302 - 315.

Melton, A.W. (1963) Implications of short term memory for a general theory of memory. J. Verb. Learn. Verb. Behav. 2, 1 - 21.

Melton, A.W. (1964) In "Categories of Human Learning" ed. Melton, A.W., N. York. Academic Press.

Melton, A.W. (1967a) In "The organisation of Recall" ed. Kimble, D.P., N. York Academy of Sciences.

Melton, A.W. (1967b) Repetition and retrieval from memory. Science, 158, 532.

Melton, A.W. and Irwin, J.M. (1940) The influence of degree of interpolated learning on retroactive inhibition and the overt transfer of specific responses. Am. J. Psychol., 53, 173 - 203.

Miller, G.A. (1957) The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev. 63, 81 - 97.

Milner, B. (1959) The memory defect in bilateral hippocampal lesions. Psychiat. Res. Rep. 11, 43 - 52.

Milner, B. (1966) In "Amnesia" ed. Whitty, C.W.M. and Zangwill, O.L. (eds.) Butterworths, London.

Milner, B. (1968) Disorders of memory after Brain lesions in Man. Neuropsychologica. 6, 175 - 180.

Murdock, B.B. (1960) The immediate retention of unrelated words. J. Expt. Psychol., 60, 222 - 234.

Murdock, B.B. (1961) The retention of individual items. J. Expt. Psychol., 62, 618 - 625.

Murdock, B.B. (1962) The serial position effect in free recall. J. Expt. Psychol., 64, 482 - 488.

Murdock, B.B. (1963) Short term retention of single paired-associates. J. Expt. Psychol., 65, 433 - 443.

Murdock, B.B. (1965) A test of the "limited capacity" hypothesis. J. Expt. Psychol., 69, 237 - 240.

Murdock, B.B. (1967) Recent developments in short term memory. Brit. J. Psychol., 58, 421 - 433.

Murdock, B.B. (1968a) Modality effects in short term memory: storage or retrieval. J. Expt. Psychol., 77, 79 - 86.

Murdock, B.B. (1968b) Serial order effects in short term memory. J. Expt. Psychol., Mono. Supp. 76, 4, Part 2.

Murdock, B.B. and Vom Sael, W. (1967) Transpositions in Short Term Memory. J. Expt. Psychol., 74, 137 - 143.

Neisser, V. (1967) Cognitive Psychology. Appleton Century Crofts, N. York.

Nickerson, R.S. (1965) Short term memory for complex meaningful visual and configurations. Can. J. Psychol. 19, 155 - 160.

Norman, D.A. (1966) Acquisition and retention in short term memory. J. Expt. Psychol., 72, 369 - 381.

Norman, D.A. (1968) Toward a theory of memory and attention. Psychol. Rev. 75, 522 - 536.

Norman, D.A. (1969) Memory and Attention.
John Wiley and Sons, N. York.

Norman, D.A. and Waugh, N. (1968) Stimulus and response interference in recognition memory experiments.
J. Expt. Psychol., 78, 551 - 559.

Norman, D.A. and Wickelgren, W.A. (1965) Short term memory for single digits and pairs of digits.
J. Expt. Psychol., 70, 479 - 489.

Norman, D.A. and Wickelgren, W.A. (1969) Strength theory of decision rules and latency in retrieval from short term memory.
J. Of Mathematical Psychol., 6, 192 - 208.

Osgood, C.E. (1953) Method and theory in experimental psychology.
Oxford University Press, N. York.

Pagano, R., Bush, R.D.F., Martin, G. and Hunt, E.B. (1969) Duration of retrograde amnesia as a function of electroconvulsive shock intensity.
Physiology and Behaviour, 4, 19 - 22.

Peterson, L.R. (1963) In "Verbal Learning and Behaviour" Ed. Cofer, C.W. and Musgrave, B.S.
McGraw Hill, N. York.

Peterson, L.R. (1966a) Short term verbal memory and learning.
Psychol. Rev. 73, 193 - 207.

Peterson, L.R. (1966b) Short term memory.
Sci. Am. 215, 90 - 95.

Peterson, L.R. (1966c) Reminiscence in short term retention.
J. Expt. Psychol. 71, 115 - 118.

Peterson, L.R. and Peterson, M.J. (1959) Short Term Retention of Individual Items.
J. Expt. Psychol. 58, 193 - 198.

Peterson, L.R., Brewer, C.L., and Bertucco, R. (1963) A guessing strategy with the anticipation technique.
J. Expt. Psychol., 65, 258 - 264.

Phillip, J. L., Shiffrin, R.M. and Atkinson, R.C. (1967) — Effects of list length on short term memory. J. Verb. Learn. Verb. Behav. 6, 303 - 311.

Pollack, I., Johnson, P. and Knapp, P.R. (1959) — Running memory span. J. Expt. Psychol., 57, 137 - 146.

Posner, M.I. (1964) — Rate of presentation and order of recall in immediate memory. Brit. J. Psychol., 55, 303 - 306.

Posner, M.I. (1967) — Short term memory systems in human information processing. Acta Psychol., 27, 267 - 284.

Posner, M.I. and Konick, A.F. (1966) — On the role of interference in short term retention. J. Expt. Psychol., 72, 221 - 231.

Postman, L. (1961) — In "Verbal Learning and Verbal Behaviour". Ed. Cofer, C.W., McGraw Hill, N.Y.

Postman, L. (1962) — The effects of language habits on the acquisition and retention of verbal associations. J. Expt. Psychol., 64, 7 - 19.

Postman, L. (1964) — In "Categories of human learning" ed. Melton, Academic Press, N. York.

Postman, L., Jenkins, W.O. and Postman, D.L. (1948) — An experimental comparison of active recall and recognition. Am. J. Psychol., 61, 511 - 519.

Postman, L. and Phillips, L.W. (1965) — Short term temporal changes in free recall. Quart. J. Expt. Psychol. 17, 132 - 138.

Postman, L. and Keppel, G. (1968) — Conditions determining the priority of new items in free recall. J. Verb. Learn. Verb. Behav. 7, 260 - 263.

Raymond, B. (1969) Short term storage and long term storage in free recall. J. Verb. Learn. Verb. Behav. 8, 567 - 574.

Reynolds, R.W. (1965) An initiative hypothesis concerning the hypothalmic regulation of food intake. Psychol. Rev. 72, 105 - 116.

Rock, I. (1957) The role of repetition in associative learning. Am. J. Psychol., 70, 186 - 193.

Rosenberg, S. (1968) Associative facilitation in recall and recognition of nouns in connected discourse. J. Expt. Psychol., 78, 254 - 260.

Ross, (1969) Sequential visual memory and the limited magic of the number seven. J. Expt. Psychol., 80, 339 - 347.

Sachs, J. (1967a) Recognition memory for syntactic and semantic aspects of connected discourse. Percept. and Psychophys. 2, 437 - 442.

Sachs, J. (1967b) Recognition of semantic syntactic and lexical changes in sentences. Psychon. Bull. 1, 17 - 18.

Sanders, A.F. and Schroats, J.J.F. (1968) Cognitive categories and memory span. III Effects of similarity on recall. Quart. J. Expt. Psychol. 21, 21 - 28.

Schonfield, D. (1967) Memory loss with age: Acquistion and retrieval. Psych. Reps. 20, 223 - 226.

Schonfield, D. and Robertson, B. (1966) Memory storage and ageing. Can. J. Psychol. 20, 223 - 226.

Seidel, R.J. (1959) The concurrent effects of proactive and retroactive inhibition. J. Expt. Psychol. 57, 397 - 402.

Sheffield, F.D. (1961)
Theoretical considerations in the learning of complex sequential tasks from demonstration and practice. Quoted Adams, J.A. 1967. op. cit.

Shepard, R.N. (1967)
Recognition memory forwords, sentences and ~~fictions.~~ pictures
J. Verb. Learn. Verb. Behav. 6, 156 - 163.

Shepard, R.N. and Teghtsoonian, M. (1961)
Retention of information under conditions approaching a steady state.
J. Expt. Psychol., 62, 302 - 309.

Shepard, R.N. and Chang, T. (1963)
Forced-choice tests of recognition memory under steady state conditions.
J. Verb. Learn. Verb. Behav. 2, 93 - 101.

Shiffrin, R.M. and Atkinson, R.C. (1969)
Storage and retrieval processes in long term memory.
Psychol. Rev. 76, 179 - 193.

Siegal, S. (1956)
Non-parametric Statistics.
N. York, McGraw Hill.

Sitterley, T.E. (1968)
Short term retention of sequentially presented digits as a function of interdigital interval, digit duration, and series length.
J. Expt. Psychol., 78, 174 - 178.

Slamecka, N.J. (1967)
Recall and recognition in list-discrimination tasks as a function of the number of alternatives.
J. Expt. Psychol. 74, 187 - 192.

Sperling, G. (1960)
The information available in brief visual presentations.
Psychol. Mon. 74, No. 11.

Sperling, G. (1967)
Successive approximations to a model for short term memory.
Acta Psychol. 27, 285 - 292.

Stepian, L. and Serpinski. (1964) Impairment of recent memory after temporal lesions in man. Neuropsychologicia, 2, 291 - 303.

Stevens, S.S. (1951) Handbook of Experimental Psychology. John Wiley and Co. N. York.

Talland, G.A. (1968) Disorders of memory and learning. Hammondsworth, Penguin.

Teghtsoonian, R. (1965) The influence of number of alternatives on learning and performance in a recognition task. Can. J. Psychol. 19, 31 - 41.

Thorndike, E.L. and Lorge, I. (1944) The teachers' word book of 30,000 words. N. York. Teachers' college Press.

Tulving, E. (1962) The effect of alphabetical subjective organisation on memorising unrelated words. Can. J. Psychol. 16, 185 - 191.

Tulving, E. (1968) Theoretical issues in free recall. In Dixon, T.R. and Horton, D.L. eds. "Verbal behavior and General behavior theory". Englewood Cliffs. Prentice Hall.

Tulving, E. and Arbuckle, T.Y. (1966) Input and Output interference in short term associative memory. J. Expt. Psychol. 72, 145 - 150.

Tulving, E. and Pearlstone, Z. (1966) Availability versus accessibility of information in memory per word. J. Verb. Learn. Verb. Behav. 5, 381 - 391.

Tulving, E. and Patterson, R.D. (1968) Functional units and retrieval processes in free recall. J. Expt. Psychol., 77, 239 - 248.

Tulving, E. and Madigan, S.A.(1970) Memory and Verbal Learning. Ann. Rev. of Psychol., 21, 437 - 484.

Turnage, T.W. (1967) Unit-sequence interference in short term memory. J. Verb. Learn. Verb. Behav. 6, 61 - 65.

Turvey, M.T. (1967) Analysis of augmented recall in short term memory following a shift in connotation. Brit. J. Psychol., 59, 131 - 137.

Underwood, B.J. (1957) Interference and forgetting. Psychol. Rev. 64, 49 - 60.

Underwood, B.J. and Good, D. (1951) Studies of distributed practice. 1. The influence of intralist similarity in serial learning. J. Expt. Psychol., 42, 125 - 134.

Underwood, B.J. and Postman, C. (1960) Extra experimental sources of interference in forgetting. Psychol. Rev., 67, 73 - 95.

Underwood, B.J. and Freund, J.S. (1968) Errors in recognition learning and retention. J. Expt. Psychol., 78, 55 - 63.

Von Kreis (1901) Quoted gomulicki, B.R. The development and present status of the trace theory of memory. Brit. J. Psychol. Mono. Supp. 1953, No. 29.

Warrington, E.K., Kingborne, M. and Jones, M. (1966) Uncertainty and transitional probability in the span of apprehension. Brit. J. Psychol., 57, 7 - 16.

Waugh, N.C. (1962) The effect of intralist repetition on free recall. J. Verb. Learn. Verb. Behav. 1, 95 - 99.

Waugh, N.C. and Norman, D.A. (1965) Primary Memory. Psychol. Rev. 72, 89 - 104.

Wellford, A.T. (1968) Fundamentals of Skill. Methuen, London.

Weiskrantz (1966) In "Amnesia" Whitty E.W.M. and Zangwill, O.L. eds. Butterworth, London.

Weiskrantz (1967) In "The organisation of recall" ed. Kimble, D.P. Academy of Sciences. N. York.

Weissman, A. (1963) Effect of Electroconvulsive shock and seizure patterns on retrograde amnesia. J. Comp. Physiol. and Psychol., 56, 806 - 810.

Whimbey, A.E. and Fischof, V. (1969) PI in STM resulting from semantic similarity of items. Psych. Sci. 13, 127 - 128.

Wickelgren, W.A. (1965a) Acoustic similarity and retroactive interference in short term memory. J. Verb. Learn. Verb. Behav. 4, 53 - 61.

Wickelgren, W.A. (1965b) Acoustic similarity and intrusion errors in short term memory. J. Expt. Psychol. 70, 102 - 108.

Wickelgren, W.A. (1966) Phonemic similarity and Interference in short term memory for single letters. J. Expt. Psychol. 71, 396 - 404.

Wickelgren, W.A. (1968) Sparing of short-term memory in an amnesic patient: Implications for strength theory of memory. Neuropsych. 6, 235 - 244.

Wickelgren, W.A. (1969a) Coding, Retrieval and Dynamics of Multitrace Associative Memory. Paper read at symposium on Cognition: Carnegie-Mellon University.

Wickelgren, W.A. (1969b) Learned Specifications of Concept Neurons, Bull. Math. Biophys. 31, 123 - 142.

Wickelgren, W.A. and Norman, D.A. (1966) Strength models and serial position in short-term recognition memory. J. Math. Psychol., 3, 316 - 347.

Wickens, D.D., Born, D.G. and Allen, C.K. (1963) Proactive inhibition and item similarity in short term memory. J. Verb. Learn. Verb. Behav. 2, 440 - 445.

Wickens, D.D., and Clark, S.E. (1968) Osgood's dimensions as an encoding class in short term memory. J. Expt. Psychol. 78, 580 - 584.

Wickens, D.D., Clark S.E., Hill, A.F. and Wittlinger, R.P. (1968) Investigation of grammatical class as an encoding category in short term memory. J. Expt. Psychol., 78, 509 - 604.

Wolf, T.M. and Jahnke, J.C. (1968) Effects of intraserial repetition on short term recognition and recall. J. Expt. Psychol., 77, 572 - 580.

Woodworth, R.S. (1938) Experimental psychology. Holt, N. York.

Young, R.K., Sageart, J. and Lindsley, D. (1968) Retention as a function of meaningfulness. J. Expt. Psychol., 78, 89 - 94.

Zinkin, S. and Miller, A.J. (1967) Recovery of memory after amnesia induced by electroconvulsive shock. Science, 155, 102 - 104.

APPENDIX 1

APPENDIX I

EXPERIMENT I and II: THE LIMITED CAPACITY HYPOTHESIS

Presentation List

1 Toxin
2 Bagpipe
3 Gaiter
4 Koran
5 Mantel piece
6 Clemency
7 Rayon
8 Forceps
9 Refinery
10 Abbess
11 Lavatory
12 Conifer
13 Sahara
14 Tartan
15 Clique
16 Tantrum
17 Platoon
18 Acrobat
19 Midwife
20 Gladiator
21 Dysentry
22 Helmsman
23 Interlope
24 Paganism
25 Bobbin
26 Ignition
27 Polyp
28 Milliner
29 Crocus
30 Nicotine
31 Haystack
32 Teacup
33 Decimal
34 Artichoke
35 Gangplank
36 Hailstone
37 Gangrene
38 Lifeboat
39 Orphanage
40 Barnacle
41 Mucous
42 Galleon
43 Torso
44 Abbreviation
45 Panacea
46 Concerto
47 Impotence
48 Harpsichord
49 Baton
50 Dualism
51 Heraldry
52 Claret
53 Easel
54 Keyhole
55 Appellation
56 Seesaw
57 Khaki
58 Faggot
59 Settee
60 Deviation
61 Lintel
62 Pagoda
63 Termite
64 Scarecrow
65 Belfry
66 Nutshell
67 Mirage
68 Repository
69 Albino
70 Tiddlywinks
71 Bedouin
72 Limpet
73 Tirade
74 Cobra
57 Reverie
76 Tungsten
77 Archway
78 Repertoire
79 Invoice
80 Carnage
81 Rostrum
82 Zealot
83 Elixir
84 Giraffe
85 Affray
86 Periwinkle
87 Hawthorn
88 Parsonage
89 Autocrat
90 Plasma
91 Passover
92 Scrimmage
93 Cauldron
94 Digression
95 Rabies
96 Porthole
97 Bigot
98 Toadstool
99 Geyser
100 Vanguard
101 Obesity
102 Wallop
103 Jackdaw
104 Chromium
105 Sinus
106 Halibut
107 Felony
108 Gizzard
109 Whalebone
110 Adage
111 Poultice
112 Contest
113 Lunacy
114 Bison
115 Rupee
116 Hexagon
117 Mimosa
118 Vampire
119 Enigma
120 Beaker

EXPERIMENT I and II: THE LIMITED CAPACITY HYPOTHESIS

Test List

0	1	Scarecrow
0	2	Pagoda
	3	Ablution
0	4	Deviation
	5	Saga
	6	Bauble
0	7	Faggot
	8	Talcum
	9	Ellipse
0	10	Seesaw
	11	Pennant
0	12	Keyhole
	13	Tarpaulin
	14	Sinecure
0	15	Claret
	16	Flottilla
0	17	Dualism
0	18	Harpsichord
0	19	Bagpipe
	20	Parsnip
	21	Alacrity
	22	Wedlock
0	23	Koran
	24	Serenade
	25	Mohair
0	26	Nutshell
0	27	Repository
0	28	Tiddlywinks
	29	Llama
0	30	Limpet
	31	Arcade
	32	Dentistry
0	33	Cobra
0	34	Tungsten
	35	Pigtail
	36	Pugalist
0	37	Repertoire
	38	Fauna
	39	Scimitar
	40	Globule
0	41	Carnage
0	42	Clemency
	43	Arrowhead
0	44	Forceps
	45	Creeper
	46	Roulette
0	47	Abbess
0	48	Zealot
0	49	Giraffe
	50	Tiara
	51	Regency
0	52	Periwinkle
0	53	Parsonage
	54	Lethargy
	55	Assessment
	56	Pathology
0	57	Conifer
0	58	Tartan
	59	Pariah
	60	Manslaughter
0	61	Tantrum
0	62	Plasma
	63	Assizes
	64	Benigh
	65	Metabolism
	66	Ligament
0	67	Acrobat
0	68	Gladiator
0	69	Helmsman
	70	Cynic
	71	Gullet
0	72	Scrimmage
0	73	Porthole
	74	Liason
0	75	Digression
	76	Graveyard
	77	Jaundice
0	78	Toadstool
0	79	Vanguard
0	80	Paganism
0	81	Nicotine
	82	Priority
	83	Brack
0	84	Milliner
	85	Retaliation
0	86	Ignition
	87	Citation
	88	Goldfinch
	89	Diction
0	90	Concerto
0	91	Teacup
	92	Dissection
0	93	Artichoke
0	94	Abbreviation
	95	Gazelle
	96	Cabal
0	97	Hailstone
0	98	Lifeboat
	99	Bequest
	100	Hairpin
	101	Juggler
0	102	Beaker
0	103	Hexagon
	104	Guffaw
0	105	Vampire
0	106	Bison
0	107	Cortex
	108	Gloworm
	109	Incisor
0	110	Wallop
0	111	Chromium
	112	Handcuffs
0	113	Barnacle
0	114	Adage
0	115	Gizzard
0	116	Halibut
	117	Hebrides
	118	Cannibalism
	119	Turbine
0	120	Galleon

0 = Old items

APPENDIX 2

APPENDIX 2

EXPERIMENT III: SEMANTIC CONFUSION IN SHORT TERM MEMORY

Presentation List: Experimental

1	Faggot	31	Kitchen
2	Spot	32	Winkle
3	Box	33	Drudge
4	Pennant	34	Tin
5	Lake	35	Norway
6	Moon	36	Station
7	Parsnip	37	Robin
8	Koran	38	Ground
9	Dog	39	Sizzle
10	Arcade	40	Tree
11	Perch	41	Duct
12	Carnage	42	Tantrum
13	Zealot	43	Barnacle
14	Thrush	44	Worm
15	Oboe	45	Snow
16	Meat	46	Flute
17	Chair	47	Grass
18	Slug	48	Gullet
19	Wife	49	Lead
20	Soil	50	Teacup
21	Dress	51	Pike
22	Cobra	52	Denmark
23	Giraffe	53	River
24	Hat	54	Doctor
25	Scorch	55	Hailstone
26	Bank	56	Handcuffs
27	Crypt	57	Market
28	Stream	58	Baby
29	Gate	59	Gizzard
30	Wrack	60	Harpoon.

Identical with p 229 !

APPENDIX 2

EXPERIMENT III: SEMANTIC CONFUSION IN SHORT TERM MEMORY

Where is Test List ?

Presentation List: Control

1	Faggot	31	Kitchen
2	Spot	32	Wrinkle
3	Box	33	Drudge
4	Pennant	34	Bin
5	Lake	35	Fairway
6	Moon	36	Station
7	Parsnip	37	Robber
8	Koran	38	Ground
9	Dog	39	Muzzle
10	Arcade	40	Tree
11	Search	41	Duct
12	Carnage	42	Tantrum
13	Zealot	43	Baronet
14	Hush	44	Squirm
15	Noble	45	Snow
16	Meat	46	Fluke
17	Chair	47	Grass
18	Slum	48	Gullet
19	Wife	49	Head
20	Spoil	50	Teacup
21	Dress	51	Pine
22	Cobra	52	Dent
23	Giraffe	53	Quiver
24	Hat	54	Doctor
25	Scorch	55	Hailstone
26	Bank	56	Handcuffs
27	Crypt	57	Market
28	Street	58	Baby
29	Gate	59	Gizzard
30	Wrack	60	Harpoon

APPENDIX 2

EXPERIMENT III: SEMANTIC CONFUSION IN SHORT TERM MEMORY

Test List

	1	Chair		21	Bank
R	2	Shail	NR	22	Vampire
	3	Carnage	R	23	Singe
NR	4	Dance	NR	24	Sea
R	5	Zinc		25	Duct
NR	6	Creeper		26	Tree
	7	Zealot		27	Snow
	8	Wife		28	Gate
NR	9	Page	R	29	Cello
NR	10	Pagoda		30	Tantrum
	11	Giraffe		31	Grass
R	12	Brook	NR	32	Car
R	13	Earth		33	Gullet
	14	Wrack		34	Kitchen
	15	Dress	R	35	Roach
NR	16	Bird	NR	36	Invoice
	17	Crypt	R	37	Limpet
R	18	Wren		38	Teacup
	19	Drudge	NR	39	Gangerine
	20	Hat	R	40	Sweden

R = New Items related to Experimental Presentation List Items.

NR = New Items unrelated to Experimental Presentation List Items.

APPENDIX 3

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THE LIMITED CAPACITY HYPOTHESIS AND SHORT TERM MEMORY

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ABSTRACT

This paper attempts to show that a dichotomy between short term memory (STM) and long term memory (LTM) cannot be established on the basis of evidence which claims to show that STM unlike LTM, has a limited capacity to hold information for recall.

INTRODUCTION

A theory which postulates one system is more parsimonious than another which postulates more than one. On the criterion of parsimony, therefore, it is only necessary to show that no evidence exists which can distinguish between a one memory and a two memory system theory, in order to obivate the need for a dichotomous (2-system) theory of memory. In other words, it is not necessary to show that data can *only* be handled by a single system theory, it is enough to show that it *can* be handled by a single system theory, in order to dispense with a dichotomous theory of memory. One way, therefore, of demonstrating the untenability of a dichotomous theory of memory is to make it clear that differences advanced in support of a dichotomous theory of memory, can in fact be explained by a single system theory. That STM is limited with respect to capacity has recently been claimed as an operational distinction between STM and LTM. Thus WAUGH and NORMAN (1965), ADAMS (1967) and PHILLIPS et al. (1967) among others, have recently distinguished between short and long term memory, on the grounds of the limited capacity of short term memory compared to the unlimited capacity of long term memory, and indeed Adams has tried to establish a dichotomous theory of memory partly on the basis of the limited capacity hypothesis (LCH). This paper aims at showing that the LCH cannot be used to establish a dichotomous theory of memory.

While some writers are not entirely explicit as to what is limited, whether it is capacity to process, store or retrieve, clearly any attempt to establish a dichotomous theory of memory on the basis of limited capacity rests on a limited storage capacity for short term memory as opposed to a relatively unlimited storage capacity for long term memory. Thus the limited capacity to process incoming information may be due to a massive build up in interference or rapid decay of non-rehearsed material, neither of which entails a dichotomous theory of memory. MELTON (1963) in fact uses the former explanation when accounting for rapid forgetting, in order to attack a dichotomous theory of memory, and BROWN (1958) opposes a limited capacity hypothesis with a trace decay theory of memory which does not imply a dichotomous theory of memory. Whilst BADDELY et al. (1969) in a recent paper, have suggested that the limited capacity is in terms of processing information into long term memory, this makes the assumption that the dichotomy between short and long term memory already exists, and has been proved on other grounds. This may be so, and in this paper it is not claimed that it is impossible to interpret data in terms of a dichotomous theory of memory, but only that it is not possible to establish a dichotomous theory on the basis of limited capacity.

Furthermore, different retrieval capacities can hardly be taken seriously as a basis for establishing a dichotomous theory of memory. Let us suppose that a given list of words, presented once, consists of A words which are retrievable immediately and B words which are lost immediately to retrieval. Unless these B words are all retrievable after a period of time, together with all the A words, then LTM has no unlimited retrieval capacity compared to STM and one cannot hold a dichotomous theory on this basis. Indeed all the experimental evidence points the other way, that after a rapid fall off retrieval becomes progressively, if slightly, worse over time, despite the occasional reminiscense effect. It is quite clear that retrieval over long periods of time is not unlimited relative to retrieval in STM, for any given set of items, hence any attempt to establish a dichotomy based on differing retrieval capacities of STM and LTM is untenable. This, as was pointed out earlier, leaves differences in capacity to store information as the essential prerequisite of establishing a dichotomous theory of memory on the basis of the limited capacity hypothesis.

The usual method of assessing the storage capacity of short term memory is the conventional memory span experiment, in which following a single presentation of a series of items, for instance digits, subjects are required to recall them immediately in their correct order. In a typical experiment a subject will be able to recall about 7 digits without error; above the digit span, items are rapidly forgotten; indeed rapid supra-span forgetting defines the memory span. It should be noted that memory span items themselves are rapidly forgotten in the absence of rehearsal. For Adams at least, this memory span defines the property of short term memory that does not apply to long term memory. Short term memory has a distinct limit in its capacity to hold material for recall, whereas long term memory has a large and unknown capacity.

Apart from questioning memory span as showing limited storage capacity as opposed to limited processing or retrieval capacity, memory span, as NEISSER (1967) for example points out, may have no special status, in that sub-span units are also rapidly forgotten under certain conditions of measurement; the discontinuity between material 'below' and 'above' the memory span thus disappears in certain measures of memory. Whilst Neisser makes this point with reference to the rapid forgetting of sub-span items the same point is made in another way by SHEPARD (1967), who has shown 90 % recognition in an experiment involving the successive presentation of 540 words; in other words he suggests that storage capacity may be relatively unlimited, provided one uses the appropriate measure of capacity. Apart from the theoretical problems involved in employing recognition rather than recall which will be dealt with later in the paper, certain objections to Shepard's experiments may be made on three grounds. (1) Presentation of stimuli was self-paced by the subjects, thus making transfer to LTM a theoretical possibility. (2) Because so many stimuli were involved, the total presentation time exceeded the bounds of what one might term an STM experiment. (3) Recognition consisted of the identification of the old item in a pair of new and old items presented simultaneously, leaving open the possibility that the high recognition rate resulted, not from the identification of the old item but from identifying the new item as one which was new.

AIM OF THE PRESENT EXPERIMENT

The aim of the present experiment was to explore the storage capacity of STM, taking into account the objections raised against Shepard's experiment. This was done by presenting words at the rate of one per second, approximately, for a total time of two minutes and eight seconds, and testing for recognition by presenting old and new items successively, but in random sequence, rather than simultaneously (correcting for response bias by subtracting errors of inclusion from correct identification of old items).

A second experiment was performed to show that the initial experiment described above must be considered a short term memory experiment, as defined by dichotomous theorists, and to counter certain other theoretical objections to the initial experiment which are considered in the course of the paper.

METHOD

Experiment 1

Subjects. Twenty undergraduate and postgraduate students from the University College of Swansea.

Materials. A list of 120 words (presentation list) of frequency one per million according to the THORNDIKE–LORGE word count (1944) i.e. words occurring infrequently, the meaning of which, however, would be known to a student population e.g. barnacle, bagpipe, adage. All words were of two or three syllables, and were recorded on magnetic tape at an average rate of 1.1 words per second. A second test list was also constructed, consisting of 60 words from the presentation list (every second word in the presentation list was included on the test list) and sixty new words of the same frequency as the presentation list words. The words were arranged randomly.

Design. The subjects, who were tested individually or in groups of two or three, were asked to listen passively to the presentation tape and to make no attempt to learn the items. As soon as the presentation tape was finished, items on the test list were presented successively, and the subjects were asked to indicate whether the words were old or new, and their degree of confidence in their decision. The ratings Y3 and N3 indicated that they were certain that a word was old or new respectively. Y2 and N2 indicated that they were quite confident but not certain, that the word was old or new respectively, and Y1 and N1 indicated that they thought the balance of probablity was in the appropriate direction. There was no neutral rating.

The measure of items retained was calculated by taking yes and no answers only into account. False positive items were subtracted from correct responses, and as the total number of old items on the test list was only half the number of items on the presentation list, the figure was multiplied by two to give a measure of the items retained.

Method

Experiment 2

Subjects. Nineteen undergraduate students at University College of Swansea, who had not acted as subjects in experiment 1.

Materials. The presentation and test lists were as described in experiment 1. The presentation list was recorded with greater clarity than in experiment 1, on magnetic tape at an average rate of 1.1 words per second.

Design. The experiment was divided into two parts. Immediately after the presentation tape had finished subjects who had been instructed to listen passively to it, were asked to recall as many words as possible. They were allowed to continue with this task until they either claimed they could not recall any more words or 30 seconds had elapsed from the time of writing the last word, with no sign that they could recall any further words. They then took part in a seminar on a psychological topic during which each was asked at least one question of relevance to the topic. After a minimum interval of 30 minutes they were given the same recognition task and test list as in experiment 1.

Results

In experiment 1, the mean number of items retained was 50.10 for the 20 subjects. The range or the number of items retained was 18-76. If one removes from the sample four subjects with a high response bias (i.e. with 'yes' responses greater than 75 %) the mean is 55.12. In experiment 2A, the mean number of items recalled immediately after presentation was 10.53. The mean recognition rate after 30 minutes was 37.79.

TABLE 1

Experiment 1. Number of items recognised immediately after presentation (for 20 subjects).

No. correct yes responses		Errors of inclusion (false positives)		Items retained	
1		2		(1–2) × 2	
Mean	*SD*	Mean	*SD*	Mean col	*SD*
42.95	7.21	17.90	11.02	50.10	15.72

Discussion

It must be admitted that these results are hardly surprising. ADAMS (1967) remarks that many studies show recognition superior to recall

Table 2

Experiment 2. Number of items recognised after 30 minutes (19 subjects).

No. correct yes responses		Errors of inclusion (false positives)		Items retained	
Mean	*SD*	Mean	*SD*	Mean	*SD*
38.74	5.03	19.84	6.73	37.79	12.52

Table 3

Experiment 2A. Number of items recalled immediately after presentation (for 19 subjects).

Mean no. of items correctly recalled	*SD*
10.53	2.72

by a factor of three. The importance of the present results lies in the problem posed for a limited storage capacity hypothesis. Experimental disproof of the hypothesis is, of course, hampered by the imprecise formulation of the word 'limited'. Both Adams (1967) and Waugh and Norman (1965) are thinking in terms of recall of some 7-9 items. It is obvious, however, that the number of items stored in both experiment 1 and experiment 2 is considerably in excess of this. Perhaps a more satisfactory approach is to reformulate the problem of limited storage capacity. If one continues to feed in information for what is considered to be short term memory, say two minutes, (an arbitrary figure of course, as there is no agreed time limit on STM i.e., there is no agreement as to what constitutes rapid forgetting) and one can produce evidence that storage is of high order and, at the same time, there is no ground to suppose that what forgetting there is, is due to factors other than interference or trace decay, then one has good reason to question that storage capacity is limited. Indeed one has no basis upon which to establish a dichotomous theory of memory on the basis of the limited capacity hypothesis.

As table 1 shows, there is a high order of retention under the conditions of experiment 1 outlined above, and the degree of retention must be considered the lowest estimate of information in store, as there is ample opportunity for intra-list interference, or trace decay, which will reduce the amount of information actually retrievable. These results indicate that, unless recognition is irrelevant as a measure of capacity, the evidence for establishing a dichotomous theory of memory on the basis of a limited capacity hypothesis is, at the very least, equivocal. It is true, of course, that there is nothing magical about 40 % retention as a disproof of limited storage. But what the data have shown is that a large amount of forgetting which was previously attributable to limited storage capacity (i.e. those items not recalled once the memory span has been reached) cannot now unequivocally be accounted for in such terms; what forgetting there is may be due to interference or trace decay rather than to lack of storage capacity. As noted in the introduction it is necessary to establish a dichotomy, otherwise a dichotomous theory cannot be held. Again it is not being claimed that given two systems of memory, one cannot account for the data, just that the data prevent one from establishing a dichotomous theory of memory based on a limited capacity hypothesis. The critical question of course is, 'Is recognition irrelevant as a measure of capacity?' KEPPELL (1968) and ADAMS (1967) have recently pointed to this possibility, and evidence that retrieval cues help recall but not recognition tends to support the hypothesis that recognition and recall are dichotomous processes.

HUNTER (1964) has, however, pointed out that as one moves from giving few cues to retrieval to giving many, one is going from a recall to a recognition task – presumably giving the actual item to be recognised is providing the ultimate cue: if this cannot be recognised, no further retrieval cues are likely to help. Thus it seems totally unnecessary to hold that recognition and recall are dichotomous on the basis of differential effects of retrieval cues. Again a review of work on pattern recognition by Neisser shows quite clearly that the recognition process is an extremely complex one, and is not the simple template matching that Adams appears to be considering. It may be that recognition and recall do reflect differing habit states, but as this assumption is at present unparsimonious at an explanatory level, and seemingly unparsimonious at a biological level, it cannot reasonably be maintained.

Given that a dichotomous theory cannot be established on the basis of limited capacity, can a dichotomous theory even adequately handle the experimental data of this paper? Four possible interpretations are considered below.

1. INFORMATION ENTERS DIRECTLY INTO LONG TERM MEMORY STORE

The first possibility is that information enters directly into long term memory store, bypassing the short term memory store. This, of course, raises a fundamental problem for those theorists who claim that material is in one memory system rather than another. The most common criterion which dichotomous theorists put forward is rapid recall failure and the results of experiment 2A indicate that according to this criterion at least the information of experiment 1 is in short term memory. A second criterion, time, is one which most dichotomists would accept, and it is met by the conditions of experiment 1. To argue that the items of experiment 1 have entered LTM direct is to allow that rapid recall failure and hence rapid forgetting is a characteristic of LTM as well as of STM and to remove the fundamental criterion for establishing the presence or absence of material in LTM. At the very least, to take this position is to admit that rapid recall loss of digits is no criterion for establishing the limited capacity of storage of short term memory. The items may well enter LTM direct and be rapidly forgotten in that system. Indeed even failure to recognise digits may indicate only the extent to which rapid forgetting has occurred in LTM. It appears necessary therefore, to regard the items recognised in experiment 1 as residing in short term memory store, if one is not going to compromise rapid forgetting, the major criterion for deciding whether or not material is in STM. It must be admitted that at least one dichotomous theorist, ADAMS (1967), has rejected rapid forgetting as a criterion for distinguishing short from long term memory The untenability of this position becomes apparent in the light of the fact that rapid forgetting is used by Adams as the criterion for deciding whether differing interference effects are in short or long term memory, and memory span (which is used as evidence for limited capacity in STM) is only regarded by him as indicating limited capacity in STM because of the rapid forgetting of supra-span sequences and the fact that memory span is itself subject to rapid forgetting. In other words if it is to be held that the information in experiment 1 enters LTM direct, on what grounds can one unequivocally maintain that any material does not enter LTM direct, making the postulation of a short term memory system redundant? (It is of course unparsimonious to argue that a distinction must be drawn between serialised material and non-serialised material in considering the theoretical implications of the data presented. One has then to postulate two mechanisms for rapid forgetting, as the evidence from this study is to the effect that even for non-serialised material forgetting, as measured by recall loss, is rapid.)

2. Information is transferred rapidly to long term memory

If it is claimed that material enters STM where it is either rapidly forgotten or rapidly transferred to LTM, the central problem still remains. Material which cannot be recalled in experiment 1 is rapidly forgotten and this rapid forgetting must have taken place in short term memory, long term memory being a stable memory system. One has, therefore, to suppose that the material recognised is in short term memory, in which case the limited capacity hypothesis is compromised; or it is in long term memory, in which case one must allow that the results of rapid forgetting can be measured after a very short period of time in long term memory, making it difficult to apply the criterion by which it is decided that material has not progressed beyond short term memory, i.e. rapid forgetting. One can always argue, in other words, that rapidly forgotten material is in long term memory.

A second problem also presents itself – the status of rehearsal. Whilst it has been argued that delivery of two and three syllable words at the rate of approximately one per second cannot preclude the possibility of rehearsal of material as it 'comes in', it should be noted that this objection can be raised against many STM experiments using the same rate of presentation, including many allegedly supporting dichotomous theory, e.g. BADDELEY's (1966) presentation rate was one per second; CONRAD (1964) letters presented at one every 0.75 second; COHEN and JOHANSSON (1967) digits presented at one per second, to name but a few. Nor can speeding up of presentation rate allow for the possibility of rehearsing material at the same time as fresh material is entering, one may have a shadowing phenomenon such that rehearsal can begin before the item is wholly 'in'. Indeed if this phenomenon does not occur it becomes almost impossible to rehearse three syllable words presented at one per second. Even if rehearsal were possible, however, its value as an attack on the present experiment is very dubious as rehearsal is neither a necessary nor a sufficient condition for items to enter LTM. (It is not a necessary condition if items can enter direct: it can hardly be claimed a sufficient condition for items to enter LTM direct, otherwise all rehearsed items would be available for recall, LTM not being susceptible to rapid forgetting.) As was pointed out previously, experiment 2 shows that there is rapid recall loss, hence any rehearsal present cannot be regarded as having successfully introduced material into LTM. It might be made clear that subjects were asked to listen passively and that the mean recall in experiment 2, 10.53 items, being lower than might be expected according to MURDOCK (1960) (i.e. 14-17 items approx.) indicates that it is reasonable to suppose subjects did obey instructions and did not rehearse.

3. SHORT AND LONG TERM MEMORY CAN EXIST SIMULTANEOUSLY

It might be argued that STM and LTM can exist simultaneously, and that in experiment 1, one is measuring a composite of output from STM and LTM. (This is the position taken for instance by WAUGH and NORMAN (1965).) The central problem remains; rapid recall loss, i.e. rapid forgetting cannot be said to have taken place in LTM; thus the items of experiment 1 which can be recognised only and not recalled, must be considered to be in STM. On the other hand experiment 2 indicates that a large number of items can be recognised after 30 minutes, in which case they must be considered to be in LTM. As with the previous objection either rapid forgetting must be said to have taken place in LTM, compromising the criterion by which a distinction between STM and LTM can be made, or the items recognised must be considered to be in STM, compromising the limited capacity hypothesis.

4. RECOGNITION DOES NOT INDICATE UNLIMITED CAPACITY

It might be argued that recognition involves compression of items in STM and that when STM is overloaded there is a loss of some information from each item, with the effect that whilst one might be able to store a great many items in STM, information is displaced from each item such that only recognition of each item is possible. In other words, as far as the present experiment is concerned the recognition of 50 or so items is based on the same amount of information as the recall of 10 items.

This possibility cannot be discussed in isolation from other possible mechanisms of rapid forgetting. At least four mechanisms have been put forward, interference, trace decay, displacement and compression. If, as Adams suggests, in reviewing the literature on forgetting, interference must be regarded as the only empirically defensible theory of forgetting then, of course, the limited storage capacity hypothesis must be rejected. Interference accounts for memory loss in terms other than loss of material once in store.[1] It must be emphasised that as inter-

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[1] Adams and others regard the erosion hypothesis, in which interference between items causes trace decay, as an interference theory. Whether it is a trace decay theory

ference is the most generally accepted theory of forgetting, the most plausible explanation of the present experimental data is that storage capacity in short term memory is not limited. Unless interference theory can be refuted, the evidence for limited storage capacity is equivocal.

Several psychologists, e.g. BROWN (1958), hold that forgetting is due to trace decay. As has been previously pointed out, however, even this theory, if applied to the present experimental data, does not imply limited storage capacity, as Brown points out in drawing a distinction between a limited capacity storage hypothesis and a trace decay theory for short term memory.

The third theory of forgetting, displacement, put forward by PHILLIP, et al. (1967) advances the hypothesis that after the limit of short term memory is reached, items are displaced from it, i.e. there is a total loss of all information from some items. MURDOCK (1968) has questioned this hypothesis on the basis of probe experiments, and the experimental evidence of this paper makes a displacement hypothesis seem untenable, as the loss of information is clearly not complete once the memory span has been reached.

Murdock's attack on displacement involves putting forward a compression theory in which there is some information loss for all items once the memory span has been reached, and presumably he would argue that the present experimental data support this hypothesis.

It is not clear, however, that the concept of compression differs in essence from the concept of displacement. If, as a result of compression, some information is pushed out of the memory store, this then is a form of displacement and differs from the position of Phillips et al. only in detail of what is pushed out of the store. By postulating that forgetting in short term memory is due to compression, Murdock, is of course postulating a further mechanism of forgetting in addition to interference and decay, but as far as the present experimental results are concerned there is no reason to suppose that what forgetting there is is due to compression rather than interference or decay. The evidence for compression is, in other words, still equivocal.

Elsewhere MURDOCK (1967) argues that rehearsal is a critical variable

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or an interference theory, is to a large extent a matter of semantics. As the theory is noted by Adams as being 'unashamedly offered without a whit of support', interference 'not involving trace decay', must according to Adams be regarded as the only empirically defensible theory of forgetting.

in transferring material from STM to LTM. As experiment 2A shows that only 10-53 words can be recalled immediately after presentation, one is faced with the problem of explaining how so many words are in LTM as measured by recognition after 30 minutes. (As pointed out earlier to take this position is problematic in that rapid forgetting may be said to have taken place in LTMS. However, if it is argued that the words recognised in experiment 2 are still in STM the time criterion for distinguishing between STMS and LTMS collapses as the amount of material which can be retained within 30 minutes is patently greater than 7-9 digits.) To maintain that the material is in LTMS one must presume that transfer can take place without rehearsal in that what one cannot recall one presumably cannot rehearse. Only 10.53 items were immediately recallable, whereas over 30 items were recognised after 30 minutes.

A second problem Murdock is faced with is to show that the mechanism of forgetting which he describes as compression is a short term memory phenomenon only. If compression is also a long term phenomenon it becomes impossible to decide on the basis of information loss such that recall is absent and recognition only is possible whether items are in STM or LTM. In the context of the present experiment to dichotomise between STM and LTM on the basis of compression entails claiming that forgetting which results in recall loss but not recognition loss immediately after presentation is due to compression, while after 30 minutes it is due to some other mechanism perhaps decay or interference. There appears to be no empirical ground upon which such a distinction can be based.

This paper has been concerned to show first and foremost that a dichotomous theory of memory cannot be established on the basis of the limited capacity hypothesis. The second part of the paper has pointed out some difficulties involved in interpreting the data presented in terms of a dichotomous theory of memory, even if such a dichotomy could be shown on other grounds.

The main problems are summarised below.

(1) If the items recognised in experiment 1 are claimed to have entered long term memory direct, rapid forgetting, as indicated by rapid recall loss, must be regarded as having taken place in long term memory, thus undermining the criterion by which it is 'established' that material has not entered LTM, i.e. rapid recall loss is the criterion by which it is claimed by dichotomous theorists that items have not entered LTM.

(2) If it is claimed that the items recognised in experiment 1 have been rapidly transferred from STM to LTM, then rehearsal, which is claimed

to be critical in the transfer process, cannot be regarded as being critical in this experiment. Again, if it is claimed that by the time recognition takes place the items are in LTM, it becomes impossible to establish where rapid recall loss has taken place and this undermines the criterion by which material is claimed not to have entered LTM.

(3) If the cause of forgetting in STM is claimed to be due to interference only, the limited capacity of STM cannot then be in terms of storage capacity, as interference theory accounts for forgetting in terms other than through storage loss.

(4) If the number of items recalled immediately after presentation is a measure of the storage capacity of STM (10.53 items in the case of experiment 2A), it appears difficult to account for an additional 27 items in store after a period of 30 minutes (experiment 2) and presumably in LTM. An explanation in terms of the extra items being displaced into LTM once the memory span is reached encounters the difficulties outlined in 2, above.

(5) If recognition in experiment 1 is claimed to be due to compression in STM, some means must be found of showing that recognition after 30 minutes i.e. in LTM is not due to compression, if a dichotomy between STM and LTM is to be established on the basis of limited storage capacity of STM.

References

ADAMS, J. A., 1967. Human memory. New York: McGraw-Hill.

BADDELEY, A. P., 1966. Short-term memory for word sequences as a function of acoustic, semantic and formal similarity. Quart. J. exp. Psychol. **18**, 362–365.

———, D. SCOTT, R. DRYNAN and J. C. SMITH, 1969. Short-term memory and the limited capacity hypothesis. Brit. J. Psychol. **60**, 51–56.

BROWN, J., 1958. Some tests of the decay theory of immediate memory. Quart. J. exp. Psychol. **10**, 12–21.

COHEN, R. L. and B. S. JOHANSSON, 1967. Some relevant factors in the transfer of material from short term to long term memory. Quart. J. exp. Psychol. **19**, 300–308.

CONRAD, R., 1964. Acoustic confusions in immediate memory. Brit. J. Psychol. **55**, 75–84.

KEPPEL, G., 1968. Verbal learning and memory. Ann. Rev. Psychol. **19**, 169–202.

HUNTER, I. M. L., 1964. Memory. Harmondsworth: Penguin.

MELTON, A. W., 1963. Implications of short term memory for a general theory of memory. J. verb. Learn. verb. Behav. **2**, 1–21.

MURDOCK, B. B., Jr., 1960. The immediate retention on unrelated words. J. exp. Psychol. **60**, 222–234.

MURDOCK, 1963. A test of the 'limited capacity' hypothesis. J. exp. Psychol. **69**, 237–240.
———, Recent developments in short term memory. Brit. J. Psychol. **58**, 421–433.
NEISSER, U., 1967. Cognitive psychology. New York: Appleton Century Crofts.
NORMAN, D. A., 1968. Towards a theory of memory and attention. Psychol. Rev. **75**, 522–536.
PHILLIPS, J. L., R. M. SHIFFRIN and R. C. ATKINSON, 1967. Effects of list length on short term memory. J. verb. Learn. verb. Behav. **6**, 303–311.
SHEPARD, R. N., 1967. Recognition memory for words, sentences and pictures. J. verb. Learn. verb. Behav. **6**, 156–163.
THORNDIKE, E. L. and I. LORGE, 1944. The teacher's word book of 30,000 words. New York: Teachers College Press.
WAUGH, N. L. and D. A. NORMAN, 1965. Primary memory. Psychol. Rev. **72**, 89–104.

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SEMANTIC AND ACOUSTIC CODING IN SHORT- AND LONG-TERM MEMORY

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Summary.—This paper considers the evidence for semantic processing in STM. It is concluded that there is sufficient evidence of semantic processing in STM to make it impossible to dichotomize between long- and short-term memory on the basis of semantic coding being exclusively employed by long-term memory.

One of the main arguments put forward recently in support of a dichotomous theory of memory systems concerns differing interference effects in what is alleged to be short- and long-term memory. Thus Adams (1967) and Baddeley (1966) claim that semantic confusion occurs in (LTM) only and acoustic confusion in (STM) only and draw the conclusion that STM is an auditory system, distinct from LTM. Gruneberg and Sykes (1969) have recently provided empirical evidence for the presence of acoustic confusion in long-term memory and have pointed out the logical impossibility of distinguishing between STM and LTM on the basis of differing coding systems being exclusively employed by the two purported systems.

A great deal of evidence has now accumulated which indicates semantic processing in STM. Thus evidence for semantic processing in STM can be found in the work of Loess (1968), Wickens and Eckler (1968), Murdoch and Vom Saal (1967), Henley, Noyes, and Deese (1968), Turnage (1967), and Dale and Gregory (1965) among others and Baddeley (1966) himself provides evidence of semantic processing in STM. Baddeley and Dale (1966) do in fact admit some slight effects of semantic confusion in short-term memory but have tried to hold a dichotomous theory on the basis of quantitative differences between acoustic and semantic confusion, claiming that the former occurs in far greater quantity in 'STM,' the latter in far greater quantity in 'LTM.' Apart from the problems involved in comparing, quantitatively, two possibly unrelated processes, it is necessary, in order to postulate a dichotomous theory, to show a dichotomy. At the very minimum, evidence of a dichotomous function over time is required in one or both processes of interference, actual quantitative differences between the two being irrelevant, although in view of the logical problems involved in dichotomising between STM and LTM on the basis of different coding systems in the two purported memories, it is not clear how this evidence could be used. As noted above, there is empirical evidence that semantic and acoustic processing occur in both purported systems, in any case, and thus a dichotomy between STM and LTM cannot be made on the basis of short- and long-term memory employing differing coding systems.

While it is clear that there is adequate experimental evidence of semantic processing in STM, it is perhaps surprising that such evidence is required in order to refute the hypothesis that 'STM' does not employ semantic coding. That the words before one as one reads are almost instantaneously meaningful indicates that they are almost instantaneously being semantically processed, but since many words are rapidly forgotten, these rapidly forgotten words must be considered to have been in STM only (Gruneberg, 1969). Thus any attempt to attribute semantic processing to items entering LTM directly is untenable. An experimental demonstration of rapid forgetting of ordinary English sentences is contained in a paper by Martin, Roberts, and Collins (1968).

One important implication of the demonstration of semantic processing in 'STM' concerns the nature of any dichotomous theory of memory. For semantic processing to occur at all, the items processed must functionally have entered 'LTM' in that meaningfulness or even non-sensory associativity is a function of the previous history of the individual. Thus any theoretical interpretation of memory in terms of two "boxes," a short-term and a long-term "box," is untenable.

Norman (1968) has recently attacked a "box" dichotomous theory on grounds similar to those above, although he appears unwilling to allow that semantic similarity can affect retention in Primary memory and maintains a dichotomous theory on the grounds of such operational distinctions as the presence of acoustic similarity factors in Primary memory and semantic similarity factors in Secondary memory. Apart from the empirical evidence against such operational distinctions, it is difficult to reconcile these operational distinctions with Norman's view of Primary and Secondary memory as having such "direct and complete intercommunication that a formal distinction between the two is difficult to make." If such intercommunication is possible, it must be because both systems use the same coding system, otherwise such communication would not be possible. Furthermore, if, as Norman claims, the items in Primary memory which are affected by acoustical similarity are those "which are to be retained," it follows that one cannot account for differences between forgetting rates for acoustically similar and for acoustically dissimilar material in terms of acoustic interference (Baddeley, 1966), as the "extra" items forgotten in the acoustically similar groups must, according to Norman's formulation, be forgotten for reasons other than their acoustic features.

REFERENCES

ADAMS, J. A. *Human memory.* New York: McGraw-Hill, 1967.

BADDELEY, A. D. Short-term memory for word sequences as a function of acoustic, semantic and formal similarity. *Quart. J. exp. Psychol.*, 1966, 18, 362-365.

BADDELEY, A. D., & DALE, H. C. A. The effects of semantic similarity on retroactive interference in long- and short-term memory. *J. verb. Learn. verb. Behav.*, 1966, 5, 417-420.

DALE, H. C. A., & GREGORY, M. Evidence of semantic coding in short-term memory. *Psychon. Sci.*, 1966, 5, 75.

GRUNEBERG, M. M. Theoretical note: logical objections to a dichotomous theory of memory. *Psychol. Rep.*, 1969, 24, 606.

GRUNEBERG, M. M., & SYKES, R. N. Acoustic confusion in long-term memory. *Acta Psychol.*, 1969, in press.

HENLEY, N. M., NOYES, H. L., & DEESE, J. Semantic structure in short-term memory. *J. exp. Psychol.*, 1968, 77, 587-592.

LOESS, H. Short-term memory and item similarity. *J. verb. Learn. verb. Behav.*, 1968, 7, 87-92.

MARTIN, E., ROBERTS, K. H., & COLLINS, A. M. Short-term memory for sentences. *J. verb. Learn. verb. Behav.*, 1968, 7, 560-566.

MURDOCH, B. B., & VOM SAAL, W. Transformations in short-term memory. *J. exp. Psychol.*, 1967, 74, 137-143.

NORMAN, D. A. Towards a theory of memory and attention. *Psychol. Rev.*, 1968, 75, 522-536.

TURNAGE, T. W. Unit-sequence interference in short-term memory. *J. verb. Learn. verb. Behav.*, 1967, 6, 61-65.

WICKENS, D. D., & ECKLER, G. R. Semantic as opposed to acoustic coding in STM. *Psychon. Sci.*, 1968, 12, 63-64.

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THEORETICAL NOTE: LOGICAL OBJECTIONS TO A DICHOTOMOUS THEORY OF MEMORY

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J. Adams (1) in a recent defence of a dichotomous theory of memory has suggested that rapid forgetting cannot distinguish between short- (STM) and long-term memory (LTM); in other words, rapid forgetting is not a sufficient condition for allocating material to STM and stable retention is not a necessary condition for allocating material to LTM. He then goes on to distinguish between STM and LTM on the basis of two operational differences: (1) limited capacity of short-term memory as opposed to the unlimited capacity of long-term memory and (2) acoustic confusion occurring in short-term memory only and semantic confusion in long-term memory only.

It must be pointed out that the basis for holding these operational differences between short- and long-term memory rests in rapid forgetting of supra-span digit sequences in the former case; the rapid forgetting of acoustically similar material in the case of acoustic confusion and slow forgetting of semantic material in the case of semantic confusion, i.e., those aspects of a stimulus which distinguish one item from another are forgotten, rapidly in the case of acoustic confusion and slowly in the case of semantic confusion. It may be further pointed out with respect to the limited storage capacity hypotheses that it is incompatible with interference theory of forgetting which Adams holds to be the only empirically justified theory of forgetting in that interference specifically disallows that the cause of forgetting is loss of material once in store. (It is clear that Adams is referring to a limited storage capacity, as limited capacity to process information does not entail a dichotomous theory of memory.)

It is difficult to see how any dichotomous theory of memory can avoid making operational differences on the basis of rapid forgetting being a necessary and sufficient condition for material being STM.

To argue that relatively stable retention is only a sufficient condition for LTM entails the possibility that all material enters LTM direct and makes any measurement of operational differences between STM and LTM impossible. It seems clear that, if Adams is correct, as he appears to be, in assuming that rapid forgetting cannot distinguish between STM and LTM, dichotomous theory cannot be verified and being less parsimonious than continuity theory must be abandoned in favour of the latter.

REFERENCE

1. ADAMS, J. A. *Human memory.* New York: McGraw-Hill, 1967.

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ACOUSTIC CONFUSION IN LONG TERM MEMORY

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Abstract

ADAMS (1967) and BADDELEY (1966a, b) amongst others, have recently claimed that short and long term memory can be distinguished on the basis of differing interference effects between the two systems, indicating that short term memory uses an auditory coding system, unlike long term memory. Specifically, it is claimed that short term memory is subject to acoustic confusion only and long term memory to semantic confusion only, despite evidence put forward by WOODWORTH (1938) showing acoustic confusion in long term memory. The present paper reports an experiment in which a presentation list was followed, after a period of 20-25 min., by a test list containing words acoustically similar and words acoustically dissimilar to words in the presentation list. Subjects were asked to rate, on a six point scale, whether they thought the test list word was old or new. The finding that the acoustically similar words were rated significantly higher than the non-related words, indicates acoustic confusion in LTM. In addition, the paper considers the theoretical problems involved in holding short term memory to be an auditory system.

Introduction

ADAMS (1967) has recently defended a dichotomous theory of memory to a large extent on the basis of differing interference effects between short and long term memory. On the basis of the work of BADDELEY (1966b) and others he suggested a definitive operational difference between STM and LTM in terms of acoustic confusion being characteristic of STM only and semantic confusion characteristic of LTM only. Because of these differing interference effects, it was concluded that STM employs an auditory coding system, LTM a semantic coding system, by which is meant that information is stored in such a way that, in STM, forgetting leads to a failure to discriminate along an acoustic dimension, in LTM a semantic dimension is involved. In other words, short term storage is in terms of acoustic coding and long term storage is in terms of semantic coding.

BADDELEY (1966b) despite his conclusions has, in fact, demonstrated statistically significant semantic confusion effects in STM and WOODWORTH (1938) has shown acoustic confusion in long term memory. The aim of the present experiment is to provide supportive evidence for Woodworth by showing acoustic confusion in long term memory, using recognition of auditorily presented material, and to consider the theoretical problems involved in holding that short term memory storage employs an auditory coding system only.

METHOD

Subjects

Twenty-two undergraduate students at University College of Swansea. *S*s were tested in groups of three to five.

Materials

These consisted of two lists of English words, a presentation list of 40 words and a test list of 30 words.

Design

If acoustic confusion occurs in long term memory, then words acoustically similar to those heard some 20–25 min previously will be confused to a larger extent with these earlier words, than will words acoustically unrelated to earlier words.

To test this hypothesis, *S*s were asked to listen, passively, to a presentation list of 40 single syllable words of high frequency (i.e., frequency of 100 per million according to THORNDIKE and LORGE (1944)). The words were read out at a rate of approximately 1 per sec. (Care was taken to ensure that all words were both semantically and acoustically unrelated.) Upon completion of the reading of the presentation list, *S*s took part in a psychology tutorial. After 20–25 min the tutorial was interrupted and a test list was administered, consisting of 30 single syllable words of the same frequency of occurrence as words on the presentation list. Ten of the words on the test list were identical to words on the presentation list, 10 of the words were acoustically related, e.g., 'cloud' on the presentation list, 'crowd' on the test list, and 10 of the words were new. Care was taken to ensure that neither the acoustically similar nor the new test list words were in the same semantic category as other words on the lists. *S*s were instructed to give a rating for each word on the test list, immediately the word was read out, according to how confident they were that the word had or had not occurred in the presentation list. The following scale was used:

Y3	*Y2*	*Y1*	*N1*	*N2*	*N3*
Certain that word was old.	Fairly certain that word was old.	Balance of probability that word was old.	Balance of probability that word was new.	Fairly certain that word was new.	Certain that word was new.

For scoring purposes the scale extended from 1 (N3) to 6 (Y3). Administration of the test list took approximately 120 seconds.

Results and discussion

The ratings for words on the test list acoustically related to words on the presentation list were significantly higher ($p < 0.01$ sign test) than ratings for words on the test list unrelated to words on the presentation list. (The results of 18 out of 22 *S*s are in the direction of the hypothesis.) The possibility that these results might be due to misperception of words on either the test or presentation list was tested by having 10 new *S*s repeat back each item on the presentation list as it was read out at the rate of 1 per sec. The mean misperception rate, 1 word out of 40, indeed the maximum error rate of any *S*s, 2 words, would not have altered the significance of the results. Again it might be argued that the experimental procedure allows the possibility of rehearsal both during presentation and during the interval of 20–25 min before the test list was presented. This, of course, is true, but as the function of rehearsal, according to dichotomous theory, is to transfer material from STM to LTM, this objection is not relevant.

Again, as acoustic confusion occurs within 4 sec of an item on the test list being presented, it might be argued that these results show only the effect of acoustic confusion in short term memory. However, it must be pointed out that the confusion is with words that have been stored for at least 20 min, a time criterion that is considered by Baddeley (1966a) and by Adams (1967), at least, as indicating that material is in LTM.

These results then, together with those of Woodworth (1938) indicate that acoustic confusion occurs in long term memory, and hence make an operational distinction between STM and LTM on the basis of differing interference effects untenable.

It is perhaps surprising that the hypothesis that STM employs an exclusively auditory coding system and long term memory an exclusively semantic coding system, has ever been seriously entertained. If short term memory uses acoustic coding only, and long term memory semantic coding only, then transfer from short term memory to long term memory is impossible without the intervention of a mechanism which translates auditory coding into semantic coding. However such a mechanism would have to be as large short and long term memory stores combined, which makes the postulation of a short and long term memory seperate from compiler unparsimonious.

Furthermore such a compiler entails LTM being able to use an auditory coding system at any time, and makes the distinction between STM and LTM, on the basis of acoustic coding being an STM characteristic only, untenable.

A further difficulty in holding the hypothesis that only STM is subject to acoustic confusion concerns the empirical evidence provided by BADDELEY (1966a) that long term learning of acoustically confusing material can take place, and at approximately the same rate as non-confusing material. It is generally held by dichotomous theorists that material in short term memory is either transferred to long term memory or lost. As acoustic confusion is confined to STM, acoustically confused material must, according to the dichotomous position be lost, a finding, as pointed out above, not borne out by the empirical evidence.

Finally, it should be noted that evidence of acoustic confusion in STM only has no overall generality, otherwise it is difficult to see how, for instance, the congenitally deaf can learn. Indeed, CONRAD and RUSH (1965) show that the congenitally deaf do not make errors of acoustic confusion in STM where non-deaf subjects do.

REFERENCES

ADAMS, J. A., 1967. Human memory. New York: McGraw-Hill.

BADDELEY, A. D., 1966a. The influence of acoustic and semantic similarity on long term memory for word sequences. Quart. J. exp. Psychol. **18**, 302—309.

———, 1966b. Short term memory for word sequences as a function of acoustic semantic and formal similarity. Quart. J. exp. Psychol. **18**, 362—365.

CONRAD, R. and M. L. RUSH, 1965. On the nature of short term memory encoding by the deaf. J. Speech Hearing Disorders **30**, **4**, 336—343.

THORNDIKE, E. L. and I. LORGE, 1944. The teacher's word book of 30,000 words. New York: Teachers College Press.

WOODWORTH, R. S., 1938. Experimental psychology. New York: Holt.